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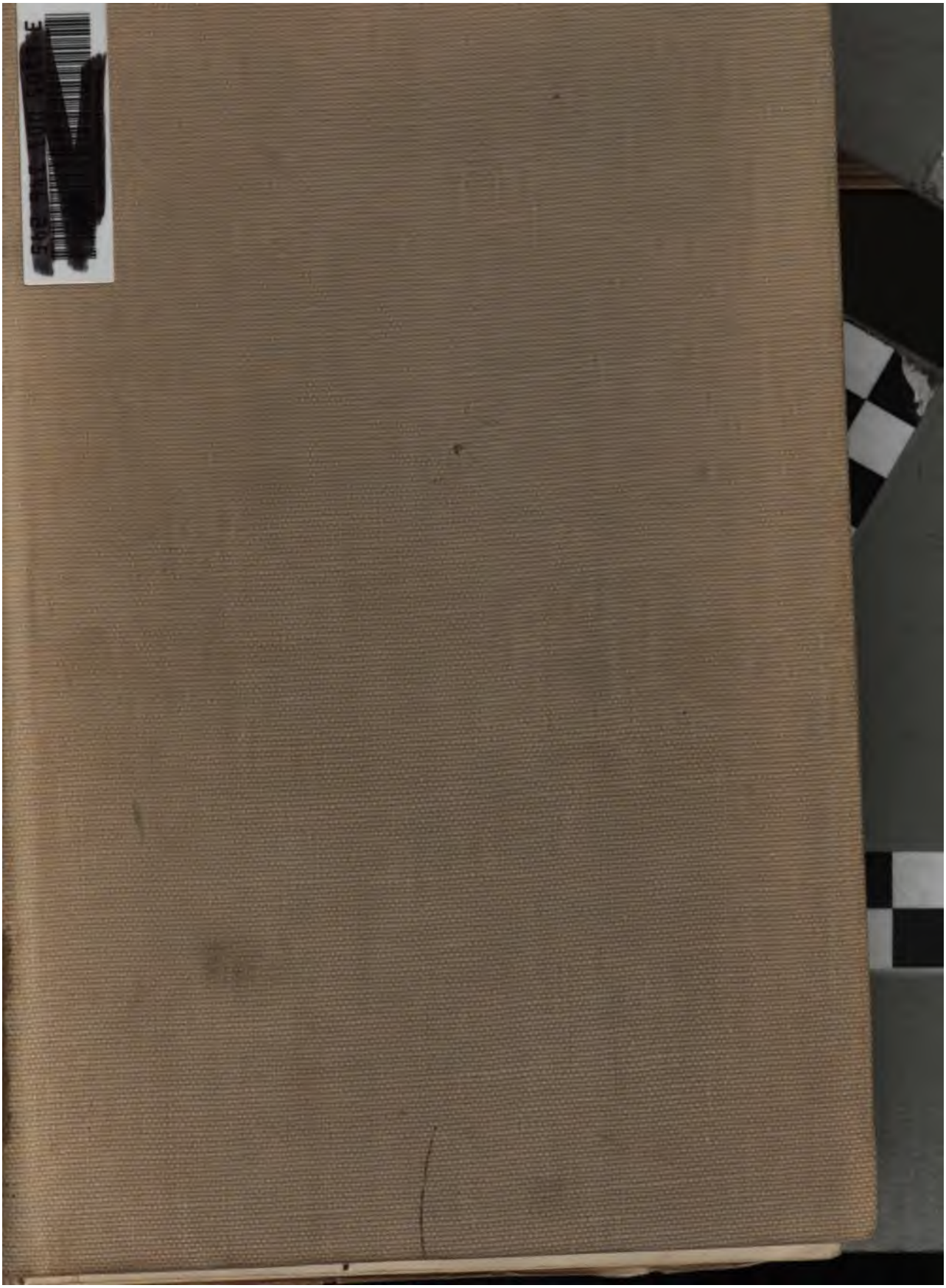

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CONTRIBUTIONS

TO

CONOMIC GEOLOGY

1906

Part II.—COAL, LIGNITE, AND PEAT

MARIUS R. CAMPBELL
Geologist in Charge

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CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1906, PART II.

COAL, LIGNITE, AND PEAT.

MARIUS R. CAMPBELL, *Geologist in Charge.*

INTRODUCTION.

By MARIUS R. CAMPBELL.

NEED OF INVESTIGATION.

The constantly growing consumption of coal in the United States has led to the opening of mines in almost every State in the Union and it has also stimulated prospecting to a marked degree. This condition of affairs has created a strong demand for information concerning the extent of the coal fields, the geologic relation of the beds, and the quality of the coal. In the comparatively unknown coal fields of the West the demand is for general information regarding the extent, number, and thickness of the beds and the quality of the coal. In the better known fields the demand is for detailed information which will enable the prospective operator to know how much of any one coal bed is available, and how it lies, so that he may locate his mine in the best position for economic work.

In order to meet this growing demand the Geological Survey has been giving more and more attention to the subject of coal, both as regards its geologic relations and its technology. The need for information in both branches is imperative, for, although the amount of coal in the various fields seems so great as to be well-nigh inexhaustible, the consumption is increasing so rapidly that already the question of a future supply of fuel is a serious one and the Government is surely justified in using every means possible to conserve the supply for the

use of future generations. Accordingly the technologic branch of the Survey is engaged in studying the fuel problems in order to devise, if possible, less wasteful methods of mining and more economical methods of utilizing the coal after it is mined.

Our chief fuels are coal, oil, and wood. Wood already is almost a thing of the past; oil, although used extensively in some parts of the country for the production of power, is necessarily of limited occurrence and before long may cease to be an important factor in the problem. Coal, therefore, is the fuel of the present, and, so far as can be seen, will continue to lead in this particular for a long time to come.

The importance of the coal industry at the present time is well illustrated by a comparison of the values of the leading mineral products of the United States for the year 1905.

Values of six of the leading mineral products of the United States in 1905.[a]

Coal	$476, 756, 963
Iron	382, 450, 000
Clay products	149, 687, 188
Copper	139, 795, 716
Oil and gas	125, 720, 254
Gold and silver	122, 402, 683

So far as fuels are concerned the work of the Geological Survey may be divided into three classes—geologic, technologic, and statistical, the last of which is in charge of the division of mineral resources. The object of this report is to give, in a brief way, a synopsis of the results accomplished in the various branches of the work during the last year in advance of the more detailed reports covering the same subjects.

GEOLOGIC WORK.

All geologic work on the mineral fuels of the United States is under the general supervision of the writer. The work is of various grades and degrees of precision, depending on the needs of the public and the conditions under which the surveys are carried on.

In that part of the country west of the 100th meridian the coal fields are comparatively unknown, and the work of the Survey is largely exploratory. Rapid reconnaissance surveys are made over large areas to determine the limits of the field and to obtain such information regarding the number and character of the coal beds and their attitude as may be possible in the present undeveloped condition of the field and with the hasty method of examination. Where the outlines of the fields are already fairly well known the work is largely devoted to a more or less detailed investigation of the number and thickness of the coal beds, the quality of the coal, and the best locations for economical development of the field.

In the eastern fields information is needed almost as badly as in the West, but the work is of a much more detailed character and involves

[a] Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906.

not only a thorough study of the geologic conditions under which the coal occurs, but also a study of the quality of the coal and its adaptability to various commercial uses.

The reports here presented cover results obtained wholly or in part during 1906. Geologic work has been done in the various States as follows:

Pennsylvania.—Since 1900 the examination of the Pennsylvania coal field has been carried on through the cooperation of the State and Federal authorities, but the field work has been done entirely by the geologists of the United States Geological Survey. In this time very detailed surveys have been made of most of the Pittsburg coal region of the southwest corner of the State, of a large area in the eastern part of the bituminous coal field in Indiana, Cambria, and Clearfield counties, and of a part of the Allegheny Valley, embracing an area of about 5,000 square miles.

All coal work in this State is under the general direction of George H. Ashley, who was assisted during the past year by W. C. Phalen, Edwin F. Lines, M. J. Munn, and Frederick B. Peck. Surveys were carried on in Cambria, Clarion, and Allegheny counties, and some of the results are given in this volume in papers entitled "Coal in the Clarion quadrangle, Clarion County, Pa.," by E. F. Lines, and "The coal resources of Johnstown, Pa., and vicinity," by W. C. Phalen.

Virginia-Kentucky.—A reconnaissance survey was made of a district in the central part of the Appalachian field under the general supervision of George H. Ashley. The building of a new branch line from the Chesapeake and Ohio Railway up Russell Fork of Big Sandy River to the Virginia line and the beginning of construction of the South and Western Railroad from the end of this branch to the Atlantic coast promises to open in the near future one of the largest and best tracts of coal land in the central Appalachian region. In order to be able to furnish information on this interesting and economically important region, a detailed reconnaissance was made by Ralph W. Stone, assisted by C. W. Dodge, on both sides of the Virginia-Kentucky State line, and the more important results will be found in three papers in this bulletin by Mr. Stone entitled "The Elkhorn coal field, Kentucky," "Coal mining at Dante, Va.," and "The Russell Fork coal field, Virginia."

Alabama.—For several years Charles Butts has been engaged in a close, detailed survey of the coal fields in the vicinity of Birmingham, including much of the Warrior basin. During the past year Mr. Butts was assisted by Chester W. Washburne, and the work was carried to the east into the Cahaba coal field. Time did not permit the survey of the entire field, but the northern part was examined thoroughly, and a brief account of the results of this work may be found in a paper by Mr. Butts entitled "The northern part of the Cahaba coal field, Alabama."

Illinois.—In Illinois the examination of the coal field is carried on both by the State Geological Survey and by the Federal organization, with the understanding that each shall supply to the other manuscript reports on the area or areas investigated. During the last year the work of the Federal Survey was confined to two 15-minute quadrangles in Gallatin, Saline, White, and Hamilton counties, and the results are embodied in a paper in this volume by Frank W. De Wolf entitled "Coal investigations in the Saline-Gallatin field, Illinois."

Arkansas.—A demand for more detailed information regarding the Carboniferous coal field of Arkansas than is contained in the reports of the State Geological Survey led the Federal organization to make an examination of this field in the early part of the past summer. The work was done by Arthur J. Collier, assisted by Carl D. Smith, Sidney Paige, and R. D. Mesler. This work is of especial value, inasmuch as it has established the identity of the principal coal beds at the east and west ends of the field, and has thrown considerable light on the distribution of the workable coals, a point that has been troubling the operators for a number of years. A brief account of this work is given by Mr. Collier in a paper entitled "The Arkansas coal field."

Montana.—The coal fields of Montana are probably more extensive than those of any other State, but they are not well known except along the main lines of railroad where mines have been opened, either to supply fuel for locomotive use or for the great copper smelters of the Butte region. The quality of the Montana coal is exceedingly varied, but as a rule only the better grades are being mined at the present time.

The most important piece of geologic work carried on in Montana during 1906 was the careful mapping of the Great Falls coal field by C. A. Fisher, assisted by W. R. Calvert, H. M. Eakin, A. J. Hazlewood, and J. D. Pollock. Geologically this field is most interesting, sinc the coal occurs in the Kootenai (Lower Cretaceous) formation, whi is not known to carry coal in any other part of the United Stat except possibly in the Black Hills region of South Dakota and W ming. The field was carefully mapped from Missouri River east along the foothills of the Little Belt Mountains as far as Stanford brief synopsis of the results is given in a paper by Mr. Fisher ent "The Great Falls coal field, Montana."

The Bear Creek and Red Lodge fields of Carbon Count examined by N. H. Darton, who traced the Red Lodge group beds for a considerable distance to the point where they are c by the overlying Tertiary rocks, and the Bridger coal bed point near the Wyoming line northward to Joliet. An ac this field by Mr. Darton is entitled "Coals of Carbon Count

The great lignite field of the eastern part of the State was by A. G. Leonard, assisted by W. R. Holgate and W.

This party made an exploratory trip from Glendive to Miles City and thence northward by way of Jordan to Hell Creek on Missouri River. An account of this trip and of the coal beds and other strata exposed will be found in a paper by Mr. Leonard entitled "Coal fields of parts of Dawson, Rosebud, and Custer counties, Mont."

Wyoming.—Wyoming is one of the great coal-producing States of the Union. The coal is extensively developed along the Union Pacific and Oregon Short Line railroads at Hanna, Rock Springs, and Kemmerer. It is also mined to some extent at Glenrock and Big Muddy on the Chicago and Northwestern Railway and along the Burlington system at Sheridan and Cambria. In addition to these well-known localities, there are immense areas of coal land along Powder River from a point north of Casper to the Montana line, in the Bighorn Basin, in Uinta County north of Kemmerer, and in Carbon County west of Rawlins.

During the past year the Hanna field of Carbon County was rather thoroughly explored by A. C. Veatch, assisted by Max A. Pishel, Max W. Ball, and Spencer R. Logan. A brief account of this work is given by Mr. Veatch in a paper entitled "Coal fields of east-central Carbon County, Wyo."

C. E. Siebenthal made a hasty examination of the coal beds in the western part of the Laramie basin, and a brief account is given by him in a paper entitled "Coal of Laramie Basin, Wyoming."

During 1905 A. C. Veatch, assisted by A. R. Schultz, made an examination of the southern Uinta County field from the Utah State line to a point north of Kemmerer. A short account of this work appeared in Bulletin No. 285, and a full report is contained in Professional Paper No. 56, entitled "Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil." During the past year this work was carried northward by Mr. Schultz, assisted by E. Eggleston Smith. The country is exceedingly rough and mountainous, but the coal fields were mapped with considerable care as far as Snake River. This region is scarcely accessible at the present time and little is known regarding the coals, but in the event of the construction of a railroad line along Snake River it seems quite possible that much of the area of this field would become accessible by branch lines from the main trunk system. A brief account of this field will be found in a paper by Mr. Schultz entitled "Coal fields in a portion of central Uinta County, Wyo."

In the central part of the State there is a large syncline of coal-bearing rocks which in most places is covered by Tertiary sediments to such a depth that it is not accessible, but here and there along the rim of the basin coal beds are exposed. This is the case in the vicinity of Lander, where there is a small coal field that was examined by E. G. Woodruff. A very brief account of this field is given by Mr. Woodruff in a paper entitled "The Lander coal field, Wyoming."

Colorado.—Through the explorations carried on by the Colorado Fuel and Iron Company and the development of mines in the best and most accessible fields, the coals of Colorado are perhaps better known than those of any other western State. Nevertheless, there are a number of areas about which little information can be obtained, and it has been the aim of the Geological Survey to explore these in advance of development.

The largest area of undeveloped coal lies in the northwestern part of the State, in Routt, Rio Blanco, Garfield, Pitkin, and Mesa counties. On the completion of the Denver and Northwestern (Moffitt) Railroad through Routt County the northern part of this great area, or the Yampa coal field, will be the first to be developed. This was examined in 1905 by N. M. Fenneman and Hoyt S. Gale, and a detailed report of their work appeared in Bulletin No. 297, entitled "The Yampa coal field, Routt County, Colo." A brief account was published also under the same title in Bulletin No. 285. During the last season this survey was extended southward across the anticline of Axial Basin to the Danforth Hills and thence along the Grand Hogback southeastward to Newcastle on Grand River. This work was done by Mr. Gale, who was assisted by A. K. Adams, A. L. Beekly, and R. D. Crawford. A brief account of this work is given by Mr. Gale in a paper entitled "Coal fields of the Danforth Hills and Grand Hogback in northwestern Colorado."

Colorado-Utah.—The great Uinta Basin, which extends from the vicinity of Crested Butte, Colo., westward into Utah, continues in the latter State along the south side of the Uinta Mountains at least as far as Castle Gate. The center of the basin is deeply covered by Tertiary sediments, and at the western extremity these overlap the upturned edges of the coal-bearing rocks and conceal them so that the limit of the field in this direction is unknown.

It is generally understood that the Book Cliffs, which form the southern margin of this basin, are coal bearing, but little or no information outside of that furnished by the established mines has been available regarding the character of the coal or the number and thickness of the beds. To supply such data George B. Richardson, assisted by W. D. Neal and Leon J. Pepperberg, carried on a rapid reconnaissance during the last season from De Beque, on Grand River, Colorado, into Utah as far as the Sunnyside mine of the Utah Fue' Company, where connection was made with the work of Mr. Ta' who, during 1905, made a careful instrumental survey of the B' Cliffs field from the Sunnyside mine westward to Castle Gate, and ' southward along the east front of the Wasatch Plateau as fa Mount Hilgard, in Sevier County. A report of Mr. Taff's work published in Bulletin No. 285 under the title "The Book Cliff field of Utah." A brief account of the results of the survey

the last year is given by Mr. Richardson in this volume in a paper entitled "The Book Cliffs coal field between Grand River, Colorado, and Sunnyside, Utah."

Utah.—During the last year Joseph A. Taff, assisted by Carl D. Smith, examined the region about Pleasant Valley, in the Wasatch Plateau, much more carefully than was possible during the previous year, and his report is embodied in a paper entitled "The Pleasant Valley coal district, Carbon and Emery counties, Utah."

The coal fields of Iron County, in southwestern Utah, were hurriedly examined during the last year by Willis T. Lee, who visited them and procured samples for chemical analysis from the anthracite of the western extremity of the field and from the bituminous coal east of Cedar City. This is the most important field of the Southwest, as it is accessible from the San Pedro, Los Angeles and Salt Lake Railroad, and some day it may furnish fuel to most, if not all, of the desert region of the southern part of the Great Basin. A brief description of the field will be found in a paper by Mr. Lee entitled "The Iron County coal field, Utah."

New Mexico.—The largest coal field in New Mexico lies in the northwest corner of the Territory, but the coals in this field are not well known, being developed only at Durango, Colo., and Monero, N. Mex., on the northern edge, and at Gallup, on the southern edge of the basin. In Contributions to Economic Geology for 1905 F. C. Schrader [a] had a brief paper embodying the results of a rapid reconnaissance examination made by himself and M. K. Shaler along the eastern edge of the basin from Durango to Gallup. During the last year the work has been continued by Mr. Shaler, assisted by James H. Gardner. They made a careful examination of the western part of the field from Durango to the southern point of the basin, about 60 miles south of Gallup. The results of this work are contained in a paper by Mr. Shaler entitled "A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico."

In addition to the regular work noted above, the writer made a hasty examination of two small coal fields in the eastern part of the Territory—one at Capitan, in Lincoln County, and the other known generally as the Una del Gato field, in Sandoval County. A brief account of the latter is contained in a paper entitled "The Una del Gato coal field of Sandoval County, N. Mex.," and of the former in a paper entitled "Coal in the vicinity of Fort Stanton Reservation, Lincoln County, N. Mex."

California.—In general the coals of California are of so low a grade as to be unable to stand in competition with fuel oil. As a consequence many of the mines have suspended operations. From time

[a] The Durango-Gallup coal field of Colorado and New Mexico; Bull. U. S. Geol. Survey, No. 285, 1906, pp. 241-258.

to time during the last few years reports have been made of the occurrence of a better grade of coal in Stone Canyon, in the southeastern part of Monterey County. In 1905 Ralph Arnold visited Stone Canyon and determined the geologic relations of this coal bed. A brief account of his work appeared in Bulletin No. 285, entitled "Coal in the Mount Diablo Range, Monterey County, Cal." During the past summer the writer found opportunity to visit this mine, and a short account of the results of the examination, as well as of those obtained from a chemical analysis, is contained in a paper entitled "Coal of Stone Canyon, Monterey County, Cal."

TECHNOLOGIC WORK.

The technologic work on fuels is under the direction of Joseph A. Holmes. Up to the spring of 1907 the work of this branch has been carried on largely at St. Louis, Mo., where it was started in connection with the exposition in 1904. The principal work of the branch has been the testing of carload samples of coal, and in order to do this systematically it was necessary for an inspector to supervise the loading of cars, and as a check to take samples from the mine furnishing the carload lot. During the last year this work has been under the charge of J. Shober Burrows, who has made an extended study of methods of sampling and the results to be obtained therefrom. A brief account of these results and a discussion of their meaning is given by Mr. Burrows in a paper entitled "The importance of uniform and systematic coal-mine sampling."

One of the most important results of the various tests for the better utilization of the fuel resources of the country is the demonstration that producer gas for power purposes can be made successfully from all grades of bituminous coal, lignite, and even peat. The results of these tests point conclusively to the substitution of producer-gas plants and gas engines for the generation of power in place of the wasteful steam engine in general use at the present time. The end of the steam engine is nearly in sight, and many people are wanting information regarding the present status of the producer and gas engine, in expectation of their installation in the near future. In order to supply unbiased information to the public on this important subject, R. L. Fernald, professor of mechanical engineering, Washington University, St. Louis, Mo., who has had charge of all tests made at the fuel-testing plant on the gas producer and gas engine, has prepared a brief statement which will be found in a paper entitled "The present status of the producer-gas power plant in the United States."

Another field of investigation which promises to have a distinct bearing on the better utilization of our coals is that of briquetting, and the present condition of the briquetting industry is summarized by Edward W. Parker in a paper entitled "Condition of the coal-briquetting industry of the United States."

COALS OF THE CLARION QUADRANGLE, CLARION COUNTY, PA.

By Edwin F. Lines.

LOCATION AND AREA.

The Clarion quadrangle is in the southeast corner of Clarion County, Pa. Its area is approximately 225 square miles, or a little more than one-third of the area of the county.

TOPOGRAPHY.

The most striking topographic feature of the area consists of the gorgelike valleys of Clarion River and its tributaries, cut 400 feet below the comparatively flat top of the general upland region. This drainage system occupies approximately the northern two-thirds of the quadrangle. The remainder of the drainage is tributary to Redbank Creek. The latter area is made up of broader valleys and gentle slopes, except in the southwest, where the valleys are again deep and narrow. Altitudes in the quadrangle range from about 1,000 feet at water level on Clarion River to 1,700 feet in the highest part of the Clarion-Redbank divide.

STRATIGRAPHY.

The formations exposed in the quadrangle extend from the upper portion of the Pocono to the lower portion of the Conemaugh. Over most of the quadrangle, however, the rocks at the surface belong to the Allegheny formation, and in this formation occur, with one possible exception, all the workable coal beds of the quadrangle. A generalized section showing the position of the coals of this formation is as follows:

General section of Allegheny formation in Clarion quadrangle.

	Feet.
Coal, Upper Freeport	3½ – 5½
Clay, plastic Limestone Clay, flint Shale	25 – 45

	Feet.
Coal, Lower Freeport	3½ - 7½
Clay, plastic; Limestone (locally developed); Sandstone and sandy shale	50 - 90
Coal, Upper Kittanning	2 - 4
Clay, plastic; Sandstone and shale; Coal; Clay, plastic; Shale; Coal, Middle Kittanning; Clay, plastic; Shale	70 - 130
Coal, Lower Kittanning	2 - 4½
Sandstone and shale	10 - 45
Iron ore	0 - 1½
Limestone, Vanport	3 - 8
Sandstone and shale	20 - 35
Coal, Clarion	1 - 2
Shale; Coal (?); Shale, sandy	20 - 40
Coal, Brookville	1 - 3

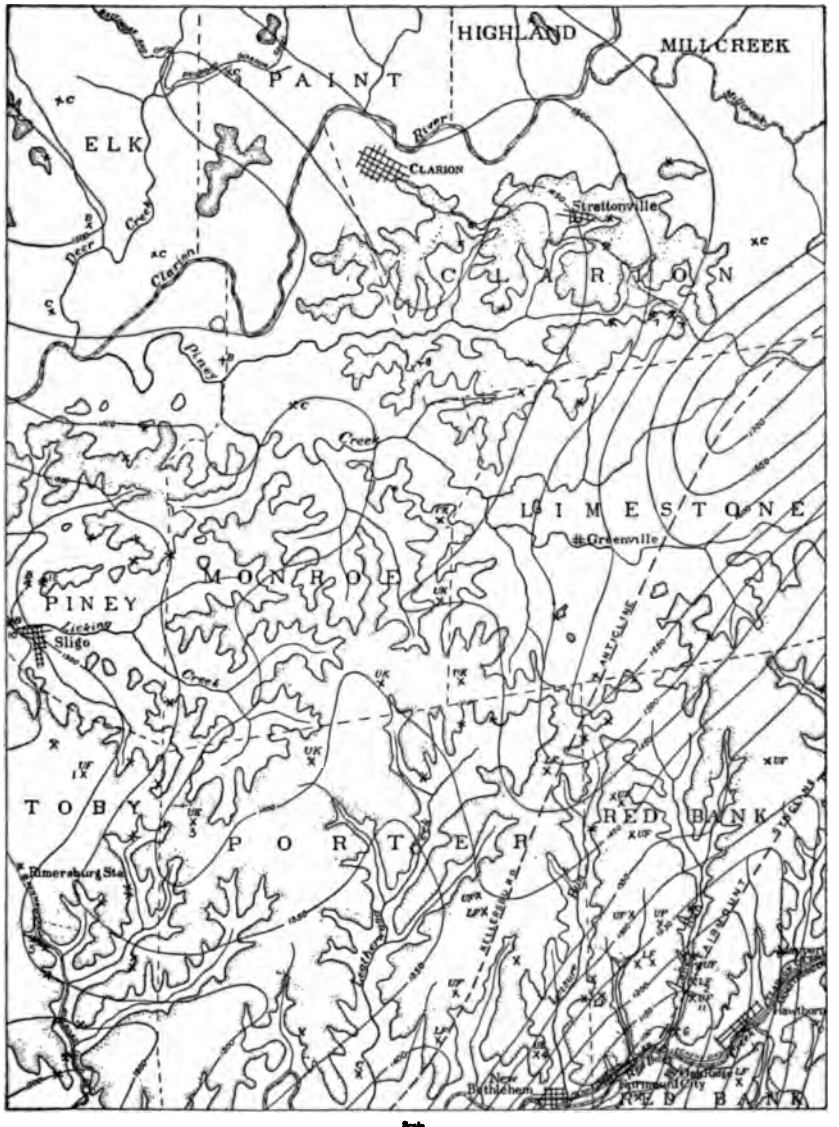
The above general section applies to the rocks over about two-thirds of the quadrangle. In the remaining third, which occupies the northwest corner, the rocks below the Lower Kittanning coal are radically different, the succession being as follows:

Section of rocks below Lower Kittanning coal in northwestern third of Clarion quadrangle.

	Feet.
Clay, plastic	5 - 15
Coal	½ - 2
Clay, plastic	5 - 10
Clay, flint	0 - 4
Sandstone	45 - 60
Coal, Clarion	2 - 4
Sandstone and shale	55 - 60
Coal, Brookville	1 - 2½

STRUCTURE.

Reference to the map (Pl. I) shows that the leading structural feature of the quadrangle is the Kellersburg anticline. The rocks on the east flank of this fold dip strongly into the Fairmount syncline, but west of the anticline the dips are slight and irregular, so that in the western and northern parts of the quadrangle there are no prominent anticlines or synclines. The dip of the rocks as a whole is a little west of south and amounts to about 300 feet in the length of the quadrangle, so that the Lower Kittanning coal, which is just above drainage level in the south, occupies the hilltops in the north. The dips range from 25 feet to the mile in the western portion of the quadrangle to 175 feet to the mile in the eastern portion.



Scale

0 1 2 3 4 5 miles

LEGEND

Contours on Lower Kittanning coal

Outcrop of Lower Kittanning coal

1 Coal mines
2 Country banks

MAP OF CLARION QUADRANGLE, PENNSYLVANIA.

Names of the coal beds on which openings have been made are indicated as follows: U F = Upper Freeport; L F = Lower Freeport; U K = Upper Kittanning; C = Clarion; B = Brookville; no mark = Lower Kittanning.

COALS.

FREEPORT COALS.

The Upper Freeport coal bed is the uppermost member of the Allegheny formation, and the Lower Freeport coal lies about 40 feet lower. These coals are present in small areas on some of the higher hills in the southern half of the quadrangle. With the exception of a few isolated hilltops in which country banks have been opened, the only commercial development of these coals is in the vicinity of New Bethlehem. The Freeport coals are of excellent quality and good thickness, but are of comparatively small extent and have been largely worked out.

On a hilltop 1½ miles south of Rimersburg, on the Painter farm, is an old opening on a coal 4 feet 4 inches thick, which the writer at present refers doubtfully to the Upper Freeport, although it is possibly the Brush Creek coal. As a rule the roof of the Upper Freeport is sandstone, and the roof of the Lower Freeport is shale. The following are typical sections:

Section of Upper Freeport coal in W. R. Saylor bank, 2 miles south of Sligo (No. 1[a]).

	Ft.	in.
Sandstone.		
Coal, bony		7
Coal	3	3
Clay.		
	3	10

Section of Lower Freeport coal in mine No. 11 of the Fairmount Coal Company, 3 miles north of New Bethlehem (No. 2).

	Ft.	in.
Clay.		
Coal	2	2½
Sulphur parting		½
Coal	1	1
Sulphur parting		½
Coal		10
Clay.		
	4	2½

KITTANNING COALS.

The Kittanning group of coals is usually described as consisting of three members, Lower, Middle, and Upper, but in this quadrangle there appear to be four or five coal beds in the interval between the Lower Freeport coal and the Vanport ("Ferriferous") limestone. The uppermost coal bed, designated Upper Kittanning in the general section, is fairly persistent and where opened averages 2½ feet in thickness except in the vicinity of New Bethlehem, where two sec-

[a] Numbers refer to corresponding numbers on Pl. I.

tions of 3 and 4 feet were measured. The following are typical sections:

Section of Upper Kittanning coal in John Mohney bank, 5 miles southeast of Sligo (No. 3).

	Ft.	in.
Shale.		
Coal	1	11
Clay parting		½
Coal		3½
Clay.		
	2	3

Section of Upper Kittanning coal in Sam Shankel bank, 1 mile northwest of New Bethlehem (No. 4).

	Ft.	in.
Coal, bony		6
Coal	1	1
Coal, bony		½
Coal	1	11
Coal, bony		6
	4	½

The next two coal beds in descending order, the lower of which is designated Middle Kittanning in the general section, are difficult to trace. Both coals were observed in the same vertical section only once, but the relation of the blossoms to adjacent rocks and the intervals between them and other coal beds that are more readily identified indicate their presence in many localities. In no place where either of these coals was identified with certainty was it possible to obtain a measured section. Neither promises anything more than a possible local value.

The Lower Kittanning coal is the most important in the quadrangle. It is persistent, uniform in thickness, and widely distributed. Its horizontal position is indicated on the accompanying map by its line of outcrop, and its elevation by the structure contours. The average thickness of 66 measured sections is 3 feet. Of the total number of measurements nine were under 2½ feet and eight over 3½ feet. No regular partings occur in the coal and the irregular ones are thin, few of them being over one-half inch in thickness. In about half the sections measured no partings were noted. From 6 to 12 inches below the top of the coal, however, occurs a binder of splinty character, from half an inch to 2½ inches thick, which is readily distinguished on fresh faces of the coal and which probably persists nearly everywhere. No attention is paid to this binder in mining. In many places the upper portion of the bed consists of 2 to 12 inches of bony coal, thus making the average thickness of clean coal 1 or 2 inches less than 3 feet. In all the openings examined the roof is shale and the floor clay. It is reported that this coal was coked for use in some of the old natural-draft iron furnaces which formerly existed in Clarion County, but a recent attempt to coke it in some

experimental ovens near Rimersburg was reported to be unsuccessful. The analyses show that the coal is rather high in sulphur and moderately high in ash. The following are typical sections of the Lower Kittanning coal:

Section of coal in mine of Acme Mining Company, 1 mile south of Rimersburg station (No. 5).

	Ft.	in.
Shale.		
Coal	1	
Binder		½
Coal	2	7
Clay.		
	3	7½

Section of coal in mine No. 1 of the Alcola Coal Company, 1 mile north of Oak Ridge (No. 6).

	Ft.	in.
Shale.		
Coal		7
Coal, bony		½
Coal	1	9
Sulphur parting		¾
Coal		11½
Clay.		
	3	4¾

Section at Baldauf mine No. 1, 2 miles southeast of Strattonville (No. 7).

	Ft.	in.
Shale.		
Coal		4½
Binder		2½
Coal	2	7½
Clay.		
	3	2½

At a distance ranging from 5 to 15 feet below the Lower Kittanning coal occurs a lower bed which is developed only in the northern half of the quadrangle. This is either a split from the Lower Kittanning or a separate bed. In favor of the theory that it is a split is the fact that in general the measurements show smaller intervals in the western than in the eastern part of the area. On the other hand, the inconsistencies in the variation and the fact that the thickness of the upper coal is not affected by the presence of the lower is in favor of the hypothesis that there are two beds. A more detailed study of the problem should be made before attempting to settle the question definitely. The thickness of the coal varies between 20 and 24 inches, except in a road section near the west edge of the quadrangle, where the beds show in one place 4 inches and in another place 9 inches thick. On the J. H. Strickler farm, 3 miles south of Clarion, an opening has been made on what appears

to be this coal. Its thickness is 24 inches. The following section was exposed at the mouth of the opening:

Section of Lower Kittanning (?) coal on farm of J. H. Strickler, 3 miles south of Clarion (No. 8).

	Ft.	In.
Coal		4
Shale		5
Coal		7
Clay	5	6
Coal, worked	1	10
	8	8

CLARION COAL.

According to the Second Geological Survey of Pennsylvania,[a] the Clarion coal in this county is split into two beds, but in this quadrangle the evidences of two coals at this horizon are not conclusive. Many sections suggest their presence, but in most of these the indications consist of coal fragments so scattered as to make the determination of the horizon uncertain. In the southern half of the quadrangle the Clarion coal is of little commercial importance. Openings have been made on it 1 mile south of Mayport and 3 miles west of New Bethlehem, and in these openings the coal measures 26 and 27 inches, respectively. In the northern half of the quadrangle the coal is much thicker, the average of four sections being 3½ feet. An 18-inch bed is reported about 5 feet below the bed that is being worked, but this coal was not seen by the writer. The Clarion coal in this region lies immmediately below the pinkish, massive sandstone which makes many flats and benches in the vicinity of Clarion River. The coal is known locally as the "Sulphur vein." The following is a sample section:

Section in coal bank on George Cook farm, one-half mile northeast of Clarion (No. 9).

	Ft.	In.
Sandstone.		
Clay	1	
Coal	2	11½
Clay.		
	3	11½

BROOKVILLE COAL.

The Brookville coal lies usually about 90 feet below the Lower Kittanning. The few sections seen indicate that it is thin and dirty over most of the quadrangle. At Sligo, however, there are two commercial mines on this coal—the Mineral Run mine, owned by J. B. Miller, and the mine of the Sligo Coal and Coke Company. The bed is about 3 feet thick and, although high in sulphur, the coal has a ready sale for steam purposes. The extent of coal havir this thickness and quality is at present not definitely known. good blossom of the coal shows in the road running south frc

[a] Rept. VV, 1880, pp. 49, 50.

Curllsville, 3½ miles east of Sligo, and 3 feet or more is said to have been uncovered on Leatherwood Creek on the George Lee farm, 2½ miles northeast of New Bethlehem.

Section of coal bed in mine of Sligo Coal and Coke Company, Sligo (No. 10).

	Ft.	in.
Sandstone.		
Coal	1	9
Sulphur parting		¾
Coal		7
Sulphur parting		½
Coal		6
Clay.		
	2	11¼

OTHER COALS.

In the northwest corner of the quadrangle there is an unusual succession of coal beds below the Lower Kittanning. A road section 1½ miles southwest of Shippensville contains seven beds ranging from 2 inches to 1 foot in thickness in a vertical distance of 140 feet. These coal beds are of small extent within the quadrangle and are probably of no commercial value. The horizon of the Mercer coals of the Pottsville formation is above drainage level in portions of the quadrangle, but these coals are not commercially important.

COAL ANALYSES.

The following analyses of coals of the Clarion quadrangle were made at the United States Geological Survey fuel-testing plant at St. Louis, Mo., from samples properly cut and quartered in accordance with the practice of the Survey, and shipped in air-tight cans.

Analyses of coal samples from Clarion quadrangle, Pennsylvania.

	Upper Freeport.		Lower Freeport.	Upper Kittanning.		Lower Kittanning.				Clarion.	Brookville.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.
Laboratory No	4111.	4171.	4172.	4176.	4177.	4116.	4170.	4055.	3951.	4173.	3953.
Analysis of sample as received:											
Moisture	3.98	5.56	3.30	5.89	4.09	2.87	2.73	4.09	3.36	4.84	2.35
Volatile matter	33.70	30.72	33.79	30.46	30.24	34.51	34.77	34.79	35.94	37.86	37.47
Fixed carbon	54.50	57.14	56.83	48.66	57.37	54.31	52.20	55.32	52.05	50.28	49.01
Ash	7.82	6.58	6.08	14.99	8.30	8.31	10.30	5.80	8.65	7.02	11.17
Sulphur	2.18	1.10	2.73	1.60	1.01	1.36	3.66	2.39	2.30	3.98	4.04
Loss of moisture on air drying	2.30	3.30	1.80	3.90	2.10	1.00	1.30	2.60	1.70	3.20	1.10
Analysis of air-dried sample:											
Moisture	1.72	2.34	1.53	2.07	2.03	1.89	1.45	1.53	1.69	1.69	1.26
Volatile matter	34.49	31.76	34.41	31.70	30.89	34.86	35.23	35.72	36.56	39.11	37.89
Fixed carbon	55.79	59.09	57.87	50.63	58.60	54.86	52.89	56.80	52.95	51.95	49.56
Ash	8.00	6.81	6.19	15.60	8.48	8.39	10.43	5.95	8.80	7.25	11.29
Sulphur	2.23	1.13	2.78	1.66	1.03	1.37	3.71	2.45	2.43	4.11	4.08

A. Two miles south of Sligo.
B. Three miles northeast of New Bethlehem.
C. Three miles northeast of New Bethlehem.
D. Five miles southeast of Sligo.
E. One mile northwest of New Bethlehem.
F. Two miles southeast of Strattonville.
G. One mile north of Oak Ridge.
H. One mile south of Rimersburg station.
I. At Sligo.
J. One and one-half miles northwest of Clarion.
K. At Sligo.

COAL RESOURCES OF JOHNSTOWN, PA., AND VICINITY.[a]

By W. C. PHALEN.

INTRODUCTION.

Location.—The area here considered is the Johnstown quadrangle, which comprises an area of 228 square miles. It lies mostly in Cambria County, Pa., but includes small parts of Somerset, Indiana, and Westmoreland counties. (See Pl. II.)

Commercial geography.—This quadrangle lies in the plateau region west of the Allegheny Front and the streams that flow through it have cut deep valleys, exposing valuable coal and clay beds. The most important streams are Conemaugh River, formed by the union of Stony Creek and Little Conemaugh River at Johnstown; Blacklick Creek, and South Fork. Conemaugh River has long been one of the most available highways of communication across the region from the coast to the Middle West; the first railroad, the old Portage and Canal Route, and the main line of the Pennsylvania Railroad have both used its valley. Thus the early development of the iron resources of the region was stimulated, and, in turn, an impetus was given to the development of its coal resources, until, at the present time, Johnstown and the towns lying in this area are among the leading coal and iron centers of western Pennsylvania. The value of the coal for 1905 was nearly $5,000,000, representing an output of about as many tons.

GEOLOGY.

STRATIGRAPHY.

The rocks outcropping in this district belong mostly in the Carboniferous system, but a few hundred feet (400 ±) of Devonian rocks are represented. Of the Carboniferous rocks only those in the Pennsylvanian series are of interest in this connection, since all the coal beds are confined to this series. As developed in this area, the Pennsylvanian comprises the Conemaugh, Allegheny, and Pottsville forma-

[a] In the field work on which these notes are based the writer was assisted by Lawrence Martin. This preliminary statement will be followed by a detailed report on the same region, which will be published as a bulletin of the Survey.

tions, in all about 1,200 feet of beds. These formations correspond, respectively, with the "Lower Barren Coal Measures," the "Lower Productive Coal Measures," and the "Millstone grit" or "Pottsville conglomerate" of the Second Geological Survey of Pennsylvania. The important coals of the area are included in the Allegheny formation, though the Conemaugh and Pottsville both contain beds that are locally workable, but probably not valuable commercially. The Allegheny formation contains at least six coal beds which at various points are thick enough to be of commercial value. Of these, not more than four, and in most places not more than two or three, are persistently valuable. The highest of these beds is the Upper Freeport or E coal. It is known about Johnstown as the Coke Yard coal and at South Fork as the Lemon or Four-foot coal. It occurs at the top of the Allegheny formation, almost directly below the usually massive Mahoning sandstone, and from 230 to 300 feet above the top of the Pottsville, or as it is locally called, the "conglomerate rock." The Lower Freeport, or D coal, is known about Johnstown as the Limestone bed, from a 2 or 3 foot layer of limestone occurring within a foot of its base. It ranges from 45 to 70 feet below the Upper Freeport coal.

The next lower coal is known as the Upper Kittanning, or C′ coal, and about Johnstown it is frequently called the Cement bed. Like the Lower Freeport coal, it is in general closely underlain by a bed of ferruginous limestone known as the Johnstown cement bed. The Upper Kittanning is an important coal about Johnstown and Windber, and is one of the most persistent and valuable coals in the quadrangle. It occurs from 80 to 105 feet below the Upper Freeport coal, though at some points, as about South Fork, this interval is slightly less. The Middle Kittanning, or C coal, is the next lower coal, but is usually not workable in this area. The next lower coal, known as the Lower Kittanning, Miller, White Ash, or B bed, is the most persistent and valuable bed in the area. It usually lies 180 to 200 feet below the Upper Freeport coal, and from 65 to 110 feet above the top of the Pottsville.

Between the Lower Kittanning coal and the top of the Pottsville there are usually at least two coal beds. One of these, occurring about 65 feet below the Miller bed, is worked at South Fork. It probably corresponds to the Brookville or A coal of the Allegheny Valley. The other bed, known as the Clarion or A′ coal, lies at a small distance above the Brookville. The upper coal showing at the roadside just opposite the pumping station of the Cambria Steel Company, west of Coopersdale, may correspond to the Clarion. It is separated by 10 feet of dark shale or clay from the lower or Brookville coal. The Mercer coal, occurring in the Pottsville formation, is as a rule not workable in this quadrangle.

STRUCTURE.

The details of the structure of this area have been only partially worked out, and it will be understood that the statements made in the following paragraphs, relating to structure, are subject to revision when the data have been studied in greater detail.

The beds which have been described above are involved in a series of nearly parallel folds, having a general northeast-southwest trend, which extend completely across the area in a series of waves from the southeast to the northwest corner. In the southeast corner the beds dip to the northwest away from the Allegheny Front into the Wilmore basin, the dips ranging as high as 300 to 350 feet to the mile. The Wilmore basin, as its name suggests, passes through the town of Wilmore, situated to the east of Summerhill and outside this quadrangle, and after crossing the reservoir site on South Fork of Little Conemaugh River passes to the southwest near the town of Elton, and from this point onward coincides very closely in position with the South Fork branch of the Pennsylvania Railroad. It is estimated that along the axis of this basin the beds rise between 800 and 900 feet in crossing from the eastern to the southern border of the quadrangle. From the Wilmore basin the beds rise northwestward to the summit of the Ebensburg (Viaduct) anticline. About South Fork the rise is comparatively sharp, at many points exceeding 400 feet to the mile. It is probable that south of Little Conemaugh River this anticlinal axis swerves slightly to the southeast and then returns to its regular southwest course. The point where it leaves the southern edge of the quadrangle is in the vicinity of Eureka No. 37 mine of the Berwind-White Coal Mining Company, but the structure of this region is not simple, the mine maps showing many slight irregularities. The Johnstown syncline is the next prominent structural feature to the west. Where it enters the quadrangle near its northeast corner, this synclinal axis lies very near the Ebensburg anticlinal axis, but farther southwest it diverges and at Johnstown curves in somewhat the same manner as the Ebensburg anticline. The next structural feature to the west is the most pronounced in the area. It is known as the Laurel Ridge anticline. This is the "first grand axis" of the Second Geological Survey of Pennsylvania. It crosses Conemaugh River about midway between Conemaugh Furnace and Coopersdale and passes to the northeast, crossing South Fork of Blacklick Creek a little over a mile southeast of Twin Rocks. Where the axis of the fold crosses the valley of Conemaugh River the lowest beds in the area are exposed. These are the red shales and sandstones of the Catskill formation, aggregating 400 feet or more above drainage level. This fold pitches

sharply to the northeast, and the Pocono sandstone, which caps the hills where the axis crosses Conemaugh River, is below drainage level where it crosses South Fork of Blacklick Creek near Twin Rocks, dropping in this distance at least 1,000 feet. The basin west of the Laurel Ridge anticline is known as the Westover basin in the Pennsylvania Geological Survey reports. More recently it has been called the Barnesboro basin by the United States Geological Survey. The course of this basin has not been very definitely determined as yet, but it is believed to enter the quadrangle near the boundary between Indiana and Cambria counties and to pass southwestward near Wehrum, crossing Blacklick Creek about a mile west of Buffington post-office. West of this basin the beds rise northwestward to the axis of the Nolo anticline, which lies very close to the northwest corner of the quadrangle. Thus it is evident that the beds in the quadrangle are involved in three broad, low waves, a condition of great practical importance in the distribution and working of the coals, fire clays, and other bedded deposits of economic importance.

Besides the principal folds there are many minor folds in these rocks. A small arch or anticline is exposed along Little Conemaugh River about a mile east of Conemaugh station. From this point westward to Johnstown depot there are many minor fluctuations, all exposed along the main line of the Pennsylvania Railroad. Between Millville and Coopersdale there is a distinct anticline. Thus it will be seen that the main broad Johnstown syncline has been subjected to many minor plications. It has been thought by some mining men that these lesser folds about Franklin and along Clapboard Run have been responsible for the so-called "faulting" which the coal exhibits in this region. The erratic behavior of the Lower Kittanning coal may possibly be due in part to this cause, but the irregularities seen by the writer are not faults, as this term is used in the geologic sense, but rather broad rolls, which seem to have pinched out the coal.

COALS.

CHEMISTRY AND USES.

In the following descriptions no attempt is made to present detailed information. This will be reserved for a future economic bulletin on this area. It is the aim here to present general facts only, chiefly additional to those heretofore published in the various volumes of the geological surveys of Pennsylvania.

The coals in this district are of the soft, lustrous, semibituminous variety. They are best adapted for steaming and domestic purposes and to a less extent for coking. They are regarded as smokeless coals owing to their small content of volatile hydrocarbons. They

are uniformly high in carbon and contain small amounts of volatile matter and moisture. The ash and sulphur contents are variable, but in general terms high as compared with other Appalachian coals—for instance, those of West Virginia and eastern Kentucky. Some analyses of samples collected according to present Survey methods are listed below:

Analyses of coal samples from Johnstown quadrangle, Pennsylvania.[a]

	Upper Freeport (E).			Lower Freeport (D).	Upper Kittanning (C').					
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.
Analysis of sample as received:										
Moisture	2.65	2.82	3.04	4.73	2.81	1.67	2.60	1.94	2.93	3.51
Volatile matter	14.86	15.61	16.27	13.78	15.07	18.52	14.10	15.81	13.47	17.16
Fixed carbon	72.38	70.32	73.47	72.27	72.64	69.14	72.05	70.77	74.06	69.04
Ash	10.11	11.25	7.22	9.22	9.48	10.67	11.25	11.48	9.54	10.29
Sulphur	2.06	2.42	2.18	1.09	1.92	3.46	2.79	3.73	1.88	2.01
Loss of moisture on air drying	2.00	2.10	2.50	4.00	2.20	1.00	2.00	1.20	2.20	2.30
Analysis of air-dried sample:										
Moisture	.66	.74	.55	.76	.62	.68	.61	.75	.75	1.24
Volatile matter	15.16	15.94	16.69	14.35	15.41	18.71	14.39	16.00	13.77	17.56
Fixed carbon	73.86	71.83	75.35	75.28	74.28	69.84	73.52	71.63	75.73	70.67
Ash	10.32	11.49	7.41	9.61	9.69	10.77	11.48	11.62	9.75	10.53
Sulphur	2.10	2.47	2.24	1.14	1.96	3.49	2.85	3.78	1.92	2.06

	Lower Kittanning (B).									
	K.	L.	M.	N.	O.	P.	Q.	R.	S.	T.
Analysis of sample as received:										
Prox. Moisture	2.70	2.03	2.81	1.78	2.21	2.24	2.63	2.79	3.12	3.07
Prox. Volatile matter	15.64	14.47	14.66	15.19	14.32	15.70	17.85	17.76	17.89	17.64
Prox. Fixed carbon	74.03	75.31	75.75	73.25	78.16	78.37	73.24	73.20	70.85	72.85
Prox. Ash	7.63	8.19	6.78	9.78	5.31	3.69	6.28	6.25	8.14	6.44
Ult. Sulphur	1.93	2.26	1.33	4.50	.47	.77	1.49	1.88	2.74	1.38
Ult. Hydrogen	.....	4.14	.....	4.16	.....	.....	.....	.....	.....	.....
Ult. Carbon	.....	79.97	.....	77.10	.....	.....	.....	.....	.....	.....
Ult. Nitrogen	.....	1.26	.....	1.41	.....	.....	.....	.....	.....	.....
Ult. Oxygen	.....	4.18	.....	3.05	.....	.....	.....	.....	.....	.....
Calorific value determined:										
Calories	.....	7,823	.....	7,612	.....	.....	.....	.....	.....	.....
British thermal units	.....	14,081	.....	13,702	.....	.....	.....	.....	.....	.....
Loss of moisture on air drying	1.80	1.40	1.90	1.10	1.60	1.60	2.00	2.10	2.50	2.50
Analysis of air-dried sample:										
Prox. Moisture	.91	.64	.93	.69	.62	.65	.64	.71	.64	.58
Prox. Volatile matter	15.93	14.67	14.94	15.36	14.55	15.95	18.21	18.14	18.35	18.09
Prox. Fixed carbon	75.39	76.38	77.22	74.06	79.43	79.65	74.74	74.77	72.67	74.72
Prox. Ash	7.77	8.31	6.91	9.89	5.40	3.75	6.41	6.38	8.34	6.61
Ult. Sulphur	1.97	2.29	1.36	4.55	.48	.78	1.52	1.92	2.81	1.42
Ult. Hydrogen	.....	4.04	.....	4.08	.....	.....	.....	.....	.....	.....
Ult. Carbon	.....	81.10	.....	77.95	.....	.....	.....	.....	.....	.....
Ult. Nitrogen	.....	1.27	.....	1.43	.....	.....	.....	.....	.....	.....
Ult. Oxygen	.....	2.99	.....	2.10	.....	.....	.....	.....	.....	.....
Calorific value determined:										
Calories	.....	7,934	.....	7,697	.....	.....	.....	.....	.....	.....
British thermal units	.....	14,281	.....	13,854	.....	.....	.....	.....	.....	.....

[a] All analyses given in this paper, unless otherwise stated, were made at the fuel-testing plant of the United States Geological Survey at St. Louis, Mo.; J. A. Holmes, in charge; F. M. Stanton, chemist.

Analyses of coal samples from Johnstown quadrangle, Pennsylvania—Continued.

	Lower Kittanning (B).								Brookville. (A).
	U.	V.	W.	X.	Y.	Z.	AA.	BB.	CC.
Analysis of sample as received:									
Prox. Moisture	2.80	3.45	2.59	3.49	3.09	2.31	1.10	0.59	2.35
Prox. Volatile matter	17.30	18.82	18.91	16.12	16.66	13.99	15.80	16.61	14.30
Prox. Fixed carbon	73.28	71.18	70.33	74.68	74.79	76.69	75.69	76.76	71.40
Prox. Ash	6.62	6.55	8.17	5.71	5.46	7.01	7.41	6.04	11.95
Ult. Sulphur	2.46	2.01	4.04	.95	1.18	1.19	1.49	.91	3.30
Ult. Hydrogen	.....	.....	.....	.....	.....	.....	.....	.....	4.22
Ult. Carbon	.....	.....	.....	.....	.....	.....	.....	.....	75.16
Ult. Nitrogen	.....	.....	.....	.....	.....	.....	.....	.....	1.13
Ult. Oxygen	.....	.....	.....	.....	.....	.....	.....	.....	4.24
Calorific value determined:									
Calories	.....	.....	.....	.....	.....	.....	.....	.....	7,382
British thermal units	.....	.....	.....	.....	.....	.....	.....	.....	13,288
Loss of moisture on air drying	2.00	3.00	2.00	2.80	2.20	1.60	.....	.....	1.80
Analysis of air-dried sample:									
Prox. Moisture	.82	.46	.60	.71	.91	.72	.....	.....	.56
Prox. Volatile matter	17.65	19.40	19.30	16.58	17.03	14.22	.....	.....	14.56
Prox. Fixed carbon	74.77	73.38	71.77	76.83	76.47	77.94	.....	.....	72.71
Prox. Ash	6.76	6.76	8.33	5.88	5.59	7.12	.....	.....	12.17
Ult. Sulphur	2.51	2.07	4.12	.98	1.21	1.21	.....	.....	3.36
Ult. Hydrogen	.....	.....	.....	.....	.....	.....	.....	.....	4.09
Ult. Carbon	.....	.....	.....	.....	.....	.....	.....	.....	76.53
Ult. Nitrogen	.....	.....	.....	.....	.....	.....	.....	.....	1.15
Ult. Oxygen	.....	.....	.....	.....	.....	.....	.....	.....	2.71
Calorific value determined:									
Calories	.....	.....	.....	.....	.....	.....	.....	.....	7,517
British thermal units	.....	.....	.....	.....	.....	.....	.....	.....	13,532

A. Conemaugh.
B. Johnstown.
C. South Fork.
D. Stony Creek near trolley bridge between Moxham and Ferndale, south of Johnstown.
E. South Fork.
F. Franklin.
G. Dale.
H. Johnstown.
I. Moxham.
J. Solomons Run, southeast of Johnstown.
K. Franklin.
L. Johnstown.
M. Near Walsall.
N. Stony Creek, Somerset County, south of quadrangle.
O. South Fork.
P. South Fork.
Q. Nant-y-Glo.
R. Nant-y-Glo.
S. Vintondale.
T. Twin Rocks.
U. Near Weber station, Black Lick Creek.
V. Twin Rocks.
W. Wehrum.
X. Ehrenfeld.[a]
Y. Ehrenfeld.[a]
Z. Scalp Level.
AA. Windber.[b]
BB. Windber.[b]
CC. South Fork.

[a] J. S. Burrows, collector. See Bull. U. S. Geol. Survey No. 290, 1906, p. 179.
[b] Analyses of sample of carload shipped by operators to St. Louis. See Bull. U. S. Geol. Survey No. 261, 1905, p. 51.

CHARACTER OF THE COAL.

UPPER FREEPORT COAL.

The highest important coal is known as the Upper Freeport coal. It is used as a domestic and steam fuel about Johnstown and South Fork, supplying also some of the brick plants at the former city. The coal from this bed is used almost exclusively for steaming purposes. It gives satisfactory results, particularly when used for generating steam in locomotives. It is not used for coking purposes in this area, though at Cresson, Gallitzin, and Bennington it is coked with satisfactory results in beehive ovens. In the by-product ovens of the Cambria Steel Company at Franklin, near Johnstown, it was found to be unsuitable owing to expansion, which quickly ruined the ovens and made it very difficult to force out the charge after it was coked. The

analyses of this coal as given on page 24 show it to be a high-carbon coal with very low moisture. The ash, especially in the first two samples collected in the Johnstown basin, is high. Its sulphur content, ranging from 2 to 2½ per cent, is also rather high.

LOWER FREEPORT COAL.

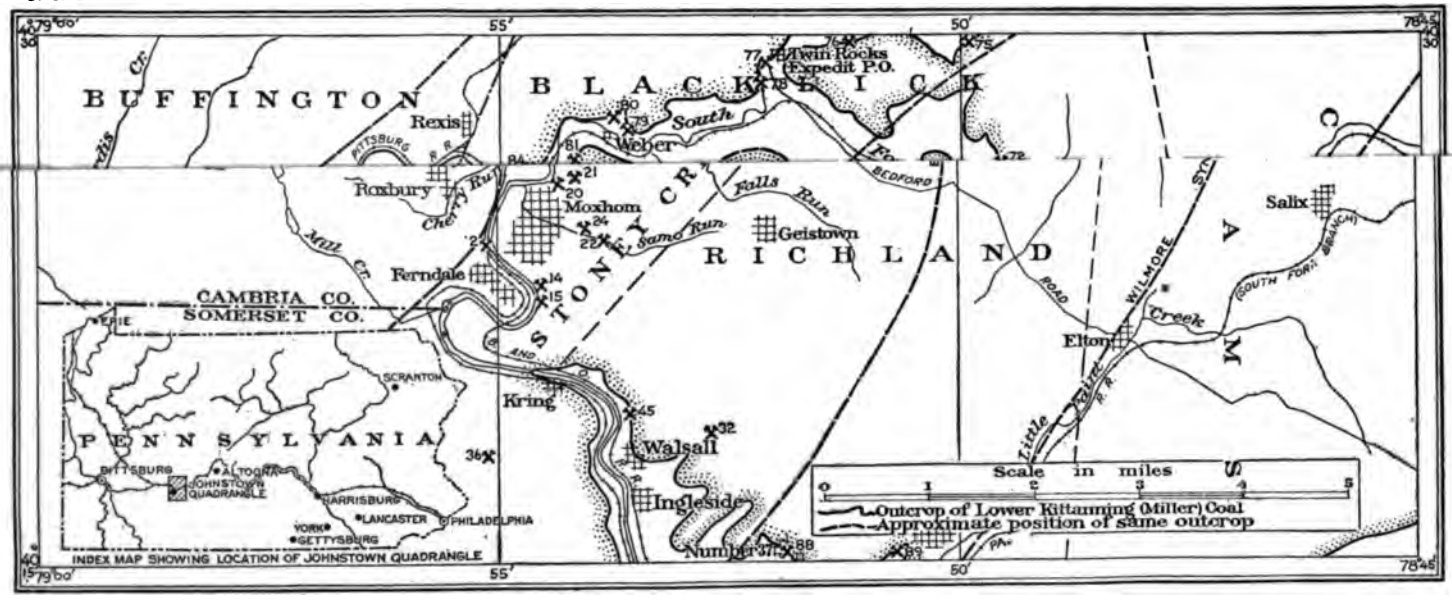
The Lower Freeport or D coal is of workable thickness about Johnstown and, though not exploited at the present time, will probably be one of the important coals of the future in this district. In the sample collected south of the city, the analysis of which is given on page 24, the clay partings were not included, as these will be discarded when this bed is worked on a commercial scale. The percentage of carbon is high and comparable with this constituent in other coals in this district. The moisture is not representative, as the material was procured near the outcrop. The ash runs rather high, but not above the average of the coals of the area. The coal from this bed is not considered good in the region about Johnstown, but the analysis of the sample collected near Stony Creek indicates that in this locality, where the coal is persistent and of workable thickness, it may be of some commercial importance.

UPPER KITTANNING COAL.

The Upper Kittanning or C′ coal is one of the most valuable beds about Johnstown and its suburbs, where it is known as the "cement seam." To the south, about Windber, recent prospecting has shown it to be even thicker than about Johnstown. As a steaming coal it is probably equal if not superior to any other coal in the Johnstown basin, and the recent demand for it in the market has been greater than the supply. The six analyses (p. 24) show a high-carbon coal with correspondingly low volatile matter. The moisture is low, but the ash and sulphur are rather high. The coal mined from this bed at Franklin mine No. 1 of the Cambria Steel Company is washed and coked at the Franklin plant. It makes a good grade of coke, but, owing to its low volatile matter, it is not considered so well adapted for beehive ovens as some of the richer gas coals of the districts farther west. When the cost of shipping coke from the region about Connellsville and Pittsburg is considered, it is found cheaper to wash and coke this coal on the ground.

LOWER KITTANNING COAL.

The next lower coal of importance in this area is the Lower Kittanning or B coal. It is widely known also as the "Miller seam." This is the most persistent of the valuable coals in the area. From the analyses given on pages 24–25, it will be seen that its fixed carbon



OUTLINE MAP OF JOHNSTOWN QUADRANGLE, PENNSYLVANIA.

Crossed hammers and appended numbers indicate coal openings.

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ranges from 70 per cent in the sample collected at Wehrum to 78 per cent in a sample collected at South Fork. Its volatile matter ranges from 14 to 19 per cent. The moisture is low, and only in a few analyses do the figures show more than 3 per cent. The ash and sulphur exhibit considerable variation, as might naturally be expected in view of the wide extent of the territory from which the samples were collected. The samples from South Fork have the lowest content both in sulphur and ash and show the excellent character of the Miller bed in this part of the Wilmore basin. As a steam coal it ranks among the very best of western Pennsylvania, the coal mined about South Fork probably equaling any other steam coal in this part of the State. As bearing on this point the following table has been prepared, showing its position among the 120-odd coals tested at the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., since the summer of 1904.[a] The column recording the number of pounds of water evaporated by 1 pound of dry coal from and at a temperature of 212° F. gives the comparative results of the coals tested, so far as these relate to their commercial values.

Chemical composition and steaming values of typical Appalachian coals.

Location.	Number of tests made.	Average chemical composition.					Average pounds of water evaporated from and at 212° F. per pound of dry coal.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	
Page, Fayette County, W. Va.	2	4.06	30.35	61.54	4.05	0.90	10.545
Do	1	2.85	30.13	64.78	2.24	1.06	10.52
McDonald, Fayette County, W. Va.	2	2.75	20.59	70.05	6.61	.98	10.36
Big Black Mountain, Harlan County, Ky.	2	5.06	34.77	56.31	3.86	.56	10.26
Rush Run Fayette County, W. Va.	2	2.12	21.91	70.73	5.24	.67	10.195
Ehrenfeld, Cambria County, Pa.	5	2.38	16.53	74.47	6.62	.95	10.186
Winifrede, Kanawha County, W. Va.	4	3.79	35.33	55.76	5.12	1.11	10.16
Acme, Kanawha County, W. Va.	4	2.93	32.66	57.64	6.77	1.23	10.115
Powellton, Fayette County, W. Va.	1	3.42	31.11	59.47	6.00	.82	10.09
Near Bretz, Preston County, W. Va.	3	4.20	28.05	60.86	6.89	1.28	10.07

The results of tests on the Ehrenfeld samples, although showing a range of 9.75 to 10.42 pounds of water evaporated per pound of dry coal used, are yet when averaged among the very best made at the testing plant. Each sample submitted to the steaming test was analyzed and the accompanying analyses represent averages of the total number made, as do the figures representing the efficiency of the coals as steam producers. It is of interest to note that the Ehrenfeld coal contains the largest percentage of fixed carbon and the lowest amount of volatile matter of all the samples. For the details of the conditions of these steaming tests the reader is referred to the publications cited above.

[a] Bull. U. S. Geol. Survey Nos. 261, 1905, and 290, 1906.

This coal is coked, but it does not rank so high as a coking coal as it does as a steam producer. A test was made on a sample of this coal with the following results:[a]

Coking test of Lower Kittanning coal from Ehrenfeld, Pa.

[Coal finely crushed. Duration of test, 51 hours.]

Coal charged	pounds	10,000
Coke produced	do	5,223
Breeze produced	do	1,600
Coke produced	per cent	52.23
Breeze produced	do	16.00
		68.23

The coke was dull gray in color, and was soft and dense. It was broken into large and small chunks, had a heavy black butt, and was hard to burn.

Analyses of coal and coke from Ehrenfeld, Pa.

	Coal.	Coke.
Moisture	3.32	0.91
Volatile matter	15.56	2.16
Fixed carbon	74.29	88.99
Ash	6.83	7.94
Sulphur	1.12	.91

The yield of coke from this test is comparatively high, but the poor quality of the coke shows that this coal does not belong among the best coking coals of western Pennsylvania and West Virginia. The coal mined at Franklin (analysis K, p. 24) is coked by the Cambria Steel Company in by-product ovens for use in the company's plant near Johnstown, and gives satisfactory results, but before coking the coal is washed, thereby adding to the cost of the coke. Even with this additional item of cost, it is found cheaper to coke this coal on the ground than to buy coke of better quality from the Connellsville region. Tests have been made by the Cambria Steel Company with the coal mined from this bed about Ehrenfeld, and the resulting coke proved well adapted to metallurgical purposes. The yield also was satisfactory. The coal mined at Nant-y-Glo from this bed has been tested in beehive ovens at Gallitzin. It produced coke of good structure, but of a rather dull appearance. As was to be expected, an insufficient amount of sulphur was volatilized. At Bennington this coal, like the Upper Freeport, shows a higher content in volatile matter than it does about South Fork and Johnstown. The Lackawanna Coal and Coke Company has experimented with it about Wehrum, but the washeries are now shut down and the results of the coking tests were not learned. The Vinton Colliery Company

[a] Bull. U. S. Geol. Survey No. 290, 1906, p. 181.

is now building a large by-product plant at Vintondale and the results will be awaited with great interest by the operators along Blacklick Creek.

LOWER COALS.

The coals below the Lower Kittanning bed have not been extensively developed in this area. At South Fork a bed lying about 60 feet below the Miller coal and known locally as the "dirty A" or "6-foot seam" has been opened. It is possible that this corresponds to the Brookville or coal A of the Allegheny Valley. It has a composition indicated by analysis CC on page 25, and from the high ash and sulphur content, aggregating more than 15 per cent, deserves the name which is often applied to it. It other respects the analysis corresponds with those of other coals of the area, being relatively high in fixed carbon and low in volatile matter.

PHYSICAL CHARACTER OF THE COALS.

The characteristics of these coal beds in addition to those already outlined are presented in the following paragraphs, and for this purpose the area may be divided into the following districts: Johnstown, South Fork, Black Lick Creek, Windber, Conemaugh Furnace.

JOHNSTOWN DISTRICT.

The Johnstown district includes the territory lying about the city of Johnstown, including its suburbs. It produced during 1905 about 1,750,000 tons of coal, valued at about $1,750,000. The important operations in this district extend from Franklin and East Conemaugh westward to Coopersdale along the main line of the Pennsylvania Railroad, and southward from the city along the Baltimore and Ohio Railroad beyond Moxhom. Important operations, though small, are also conducted on Clapboard, Hinckston, Peggys, Solomons, St. Clairs, and Samo runs. The commercial coals in this area are confined entirely to the Allegheny formation.

There are four and in places five coals of workable thickness in this district—the Upper Freeport or Coke Yard bed, the Lower Freeport or Limestone bed, the Upper Kittanning or Cement bed, and the Lower Kittanning or Miller bed. The Middle Kittanning is of workable thickness, so far as known, at only a few points and can not be classed among the commercial coals of this district. The coals, except the Lower Kittanning, lie at convenient intervals above drainage level in all the hills surrounding the city and most of its suburbs and are extensively worked.

Upper Freeport coal.—The largest operation on the Upper Freeport bed is that of the Cambria Steel Company at the Conemaugh slope, which produces yearly about 60,000 tons. The Ferndale Coal Company also operates on an extensive scale, producing about 30,000 tons yearly. There are many smaller mines worked the year round,

and many smaller banks worked only during the winter season. These small operations are more in the nature of country banks and have not been indicated on the map.

To give a fair idea of the thickness of this bed in the district, the following sections selected from well-scattered points are given:

Sections of Upper Freeport coal near Johnstown.

	Roof.	Main bench.	Parting.	Lower bench.	Floor.
		Inches	*Inches.*	*Inches.*	
Ferndale Coal Co	Shale	38	5-6	4-6	
Cambria Steel Co., Conemaugh slope	Bone	38	1	4	Clay.
Berkebile Coal Co	Sandy shale	38	3	.....	Clay.
William Davis	Shale and bone	39	4	3-4	
Davis mine, Grubtown	Shale	42	2	½-2	
George Heidingsfelder, Solomons Run	Shale	36	.....	.....	Clay.

These are average sections. They show a main bench 3 to 3½ feet thick, with a lower bench half an inch to 6 inches, separated by a bone and shale parting 1 to 6 inches in thickness. The lower bench is not invariably present and in places it is bony in character. Only the main bench is worked and the bone and shale below it may be regarded as a floor. As a rule no partings were noted in the main bench in this district. It thus differs markedly from the equivalent bed about South Fork. The maximum thickness does not exceed 4 feet; the minimum is about 2 feet and is caused by rolls, but these are extremely rare and the coal is characterized by marked uniformity. There are few or no clay veins. The roof is usually shaly in character, but is firm and little or no typical draw slate was reported. At one or two abandoned banks gas was reported and also in some of the older workings in one of the larger mines; it is nonexplosive and may be carbon dioxide.

Lower Freeport coal.—The Lower Freeport coal is known as the Limestone coal about Johnstown. It has been prospected at many points about the city and its suburbs, but it is not mined at the present time. The most promising outcrops were observed along Stony Creek from the vicinity of the Valley Coal and Stone Company's mine northward to Grubtown. In this region the following sections were measured:

Sections of Lower Freeport coal near Johnstown.

	Roof.	Top bench.	Parting (bone or shale).	Middle bench.	Parting (bone or shale).	Lower bench.	Floor.
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
Stony Creek near trolley bridge.	Massive sandstone	12	1	22	1	4	Clay.
On Baltimore and Ohio R. R., west of Loraine Steel Co.'s plant.	Sandstone or shaly sandstone.	10½-12	1½	21	1	5	Clay.
South of Kernville near Citizens' Coal Co.'s Eighth Ward mine.	Sandstone	14	1-2	24	½	4	Clay.

The coal lies in three distinct benches, separated by thin shale and bone partings. The upper bench averages about a foot thick and the middle bench about 2 feet. It is possible that in the commercial development of this bed only these two benches will be worked, and the underlying coal and bone will serve as a floor. It may be said, therefore, that from 2½ to 3 feet of good coal are present. Immediately over the coal are usually a few inches of bone and black shale, overlain by either sandy shale or massive sandstone.

On Peggys Run, near Franklin, this coal has been prospected by the Cambria Steel Company. It is reported 4 feet thick, but so badly broken up by partings that it is not commercially valuable.

Upper Kittanning (Cement) bed.—The Upper Kittanning coal outcrops at a height above drainage level that is convenient for exploitation at practically all points about Johnstown. West of the city the operations of the Cambria Steel Company in the Rolling Mill mine have been pushed westward in Upper Yoder Township beyond Mill Creek, and the coal has showed no indication of becoming too thin to work. Where observed along Bens Creek in Somerset County it is also of workable thickness. The westward dips toward the Johnstown basin carry this bed below drainage level less than a mile east of the Baltimore and Ohio tunnel south of Moxhom.

This coal is the most extensively exploited of all the beds in this district. It is worked on a commercial scale from Franklin as far west as Coopersdale and to the south beyond Moxham. Many operations, though small, are conducted along Solomons and Samo runs. The mines in operation about the city may be seen from the accompanying map (Pl. II, p. 20). One of these mines, the Rolling Mill mine of the Cambria Steel Company, is the largest in the area and one of the largest in the State, having a daily output of about 3,000 tons. The thickness of this coal may be seen from the following sections, selected from well-scattered points:

Sections of Upper Kittanning coal in Johnstown district.

	Roof.	Main bench.	Floor.
		Inches.	
Cambria Steel Co., Rolling Mill mine..	Shale or sandstone underlain by 4 to 8 inches of bone.	36–39	Shale underlain by limestone.
Valley Coal and Stone Co.....	Sandstone underlain by 8 to 10 inches of bone.	54	Shale.
Kelso Smokeless Coal Co.....	Shale.....	62	Shale.
Suppes Coal Co.....	Shale.....	42	Shale.
Natural exposure near East Conemaugh.	Sandstone.....	35½	Limestone.
Samuel Fuge, Cambria City.....	Shale underlain by 1 inch of bone	32	Shale.

This bed varies somewhat in thickness about Johnstown, but averages between 3 and 3½ feet of coal. Rarely does it exceed 4 feet, and

at a few mines less than 3 feet has been measured. South of the city it is thicker, and along Stony Creek, on the Baltimore and Ohio Railroad, the sections average about 5 feet of coal. This thick coal continues southward to the Windber district. There is usually a thin bony streak at the top of this bed which is discarded in mining, and locally a few inches of bone at the bottom; but the rest of the bed is good, clean coal, generally of uniform quality throughout. In a few mines the upper foot is reported soft and the lower harder than the average. The roof of the coal is either very dense shale or sandy shale and sandstone and gives no trouble whatever. The floor is usually a few inches of firm shale, closely underlain by the cement bed. The coal is remarkably uniform and few rolls are reported. Clay veins are, however, rather numerous and occasionally considerable annoyance is caused by gas, necessitating the use of safety lamps.

Middle Kittanning coal.—As a rule the Middle Kittanning coal is not workable in this district, though it is very persistent and hence serves as an additional check on the identity of the beds above and below. It has been opened at Coopersdale, where it is about 25 feet above the Lower Kittanning coal, at the brick plant of A. J. Hawes & Sons (Limited), and shows a thickness of 30 inches, with more concealed. It is also of workable thickness at the head of Solomons Run. Though it is locally workable, it can not be classed among the commercial coals of the district.

Lower Kittanning coal.—Immediately about Johnstown the Lower Kittanning coal is below drainage level and the mines working it are either slopes or shafts. The rise of the beds brings the coal above drainage level east of the city, and it is worked by drifts at Franklin and East Conemaugh and on Clapboard Run. It is also above drainage level west of the city, and is worked near Coopersdale, west of Morrellville, and on St. Clair and Laurel runs. It has been opened on Stony Creek south of Kring.

This coal is of importance in all parts of the quadrangle. The developments on it are important and extensive, as will be seen from the map (Pl. II, p. 20). A few of the representative sections in the region about Johnstown are as follows:

Sections of Lower Kittanning coal ("Miller seam") near Johnstown.

	Roof.	Main bench.	Parting.	Lower bench.	Floor.
		Inches.	*Inches.*	*Inches.*	
W. J. Williams, Kernville	Sandstone or shale	36–42	.....	.....	Shale.
Citizens' Coal Co., Adams street	Shale	42	.....	.....	Fire clay.
A. J. Hawes & Sons (Limited) shaft	Shale or sandstone	37	14	4½	Do.
A. J. Hawes & Sons (Limited), Coopersdale.	do	43	7	11	Do.
Cambria Steel Co., Franklin No. 2	Sandstone or shale	42–44	.....	.....	Fire clay and shale.
Keystone Coal and Coke Co., Conemaugh mine.	Shale	46	6–10	8–14	Clay.

The workable coal is present in a single bench ranging mainly from 3 to 3½ feet in thickness, though locally it reaches 4 feet. Below the main bench and separated from it by a few inches of shale and bone there is commonly a lower bench from 3 inches to a foot thick. This lower coal is usually not worked. Below the lower bench or, in its absence, below the main bench, there is uniformly a thick bed of fire clay. In nearly all the coal mines about Johnstown the under clay is mined in addition to the coal, though, of course, not on anything like the same scale. The roof of the coal is hard and firm and gives no trouble whatever. There are few or no clay veins. The floor is irregular, and numerous rolls are reported which in many places cut out the coal. At Franklin and along Clapboard Run much difficulty has been experienced on account of the irregular character of the floor. These irregularities have led to much expensive dead work near Franklin and have caused the abandonment of large operations along Clapboard Run.

Lower coals.—Coals lower than the Lower Kittanning are exposed in this district. At Coopersdale the Pottsville sandstone appears at road level just west of the brick plant of A. J. Hawes & Sons (Limited). Just above the top of the Pottsville there are two small coal beds exposed, separated by about 10 feet of dark shale. The section is as follows:

Section above Pottsville formation near A. J. Hawes & Sons' brick plant, Coopersdale.

	Ft.	In.
Shale, dark	10+	
Coal	1	0–4
Shale, black, with siliceous limestone concretions	10	
Coal		5½
Shale and bone		4
Coal	1	0–5
Shale and bone		0–10
Sandstone, massive, top of Pottsville.		

The coals are each less than 1½ feet thick. The lower and upper probably correspond with the Brookville (A) and Clarion (A′) coals, respectively, of the Allegheny Valley. One of these coals at least is exposed on Clapboard Run, but is so badly broken by partings as to be of no value commercially. South of Moxhom on Stony Creek the horizon of these lower coals is also brought above drainage level, but the data on the coals are so meager that it is uncertain whether they will be generally workable in this vicinity or not.

SOUTH FORK DISTRICT.

The South Fork district includes the territory about the towns of South Fork and Mineral Point. In 1905 it produced about 1,400,000 tons of coal, valued at $1,500,000.

The important coals are all included in the Allegheny formation, though higher coals have been worked, but without success. The coals rise above drainage level just east of Ehrenfeld station and on South Fork of Little Conemaugh River just at the southern part of the town of South Fork. They are present in the hills along Little Conemaugh River to the west beyond Mineral Point.

Upper Freeport coal.—The highest workable coal in this district is the Upper Freeport. It has been opened by the Pennsylvania, Beech Creek and Eastern Coal Company at Ehrenfeld, and by the South Fork Coal Company and H. C. and O. M. Stineman west of South Fork. Its character is indicated by the following sections:

Sections of Upper Freeport coal near South Fork.

	Roof.	Top bench.	Parting.	Middle bench.	Parting.	Lower bench.	Floor.
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
South Fork Coal Co.	Shale	2	4-12	18	½-2	18	Clay.
H. C. Stineman, No. 5	Shale	3	¾	10	2	20	
Pennsylvania, Beech Creek and Eastern Coal Co., No. 8, Ehrenfeld	Shale			24	2	22½	
O. M. Stineman, No. 3		3	½	11	2	22	Clay.
Cut near Ehrenfeld station	Shale			23½	2	20	Clay.

The bed may consist of either two benches or of three of which only the two lower are workable, and in this respect it differs essentially from the same coal about Johnstown. About Ehrenfeld only two benches were observed. The upper of the workable benches ranges in thickness from 1 foot to 2 feet and the lower from 1½ to 2 feet. The bone or shale parting between the two main benches ranges from one-half inch to 2 inches. It is very persistent in this district and is usually also present in this bed along the southeast margin of the Wilmore basin.

Upper Kittanning coal.—The coal known as the Cement bed about South Fork probably corresponds to the Cement bed of Johnstown. It has been opened by H. C. Stineman and O. M. Stineman west of the town, and by Charles Hutzel and Robert A. Giles in the town itself. The coal ranges from 3 to 3½ feet in thickness, usually without any partings, and has a hard shale roof which gives no trouble. A few inches below the base of the coal lie 3 feet or more of limestone. The sections given below show the character of this coal.

Sections of Upper Kittanning coal at South Fork.

	Roof.	Main bench.	Clay or shale.	Limestone.
		Inches.	*Inches.*	*Feet.*
Robert A. Giles	Shale	36	9	2½
Charles Hutzel	Shale and bone	34	8	3½-4
H. C. Stineman, No. 6	Shale and bone	42		
O. M. Stineman, No. 3½	Shale	36		

The coal is bright, lustrous, and of good quality, and though the single analysis (E, p. 24) shows it to be on a par with the Cement bed in the Johnstown basin its general reputation is not so good.

Lower Kittanning coal.—This coal occurs at a distance of 160 feet below the Upper Freeport coal immediately about South Fork. It is the most extensively worked coal in this district, there being no less than thirteen large and active operations on it at the present time. These operations are conducted immediately about the town, but include also two small mines near Mineral Point. All the mines are situated near the main line of the Pennsylvania Railroad. The coal makes its appearance above drainage level in the town and is exposed in the valley of Little Conemaugh River westward most of the distance to the Johnstown district. The Miller bed in the South Fork district maintains its usual section, as follows:

Sections of Lower Kittanning coal ("Miller bed") near South Fork.

	Roof.	Main bench.	Parting.	Lower bench.	Floor.
		Inches.	*Inches.*	*Inches.*	
Valley Smokeless, No. 3 (Radnor mine)	Shale or sandstone	54	1	21-24	Fire clay.
Pennsylvania, Beech Creek and Eastern Coal Co., No. 3.	Shale with bone, 3 inches.	46	2-3	4	Fire clay.
South Fork Coal Mining Co., No. 1	Shale	48	3-12	2-8	Fire clay.
Stineman Coal and Coke Co., No. 2	Shale	48	3-15	15-36	Fire clay.
Argyle Coal Co., No. 3	Shale	48	6-12	4-24	Fire clay.
Stineman Coal Mining Co., No. 1	Shale or sandstone	42	12	2-9	Fire clay.

Its main bench averages nearly 4 feet and in some places is 5 feet in thickness, with no partings. The double structure which is fairly persistent in the Johnstown district is even more apparent about South Fork. Some of the mines, however, show it only here and there. In other physical aspects this coal resembles the Miller bed about Johnstown. Its roof of dense shale or sandstone, the general absence of draw slate or clay veins, and the irregular floor are all common to the bed in both districts. The top few inches are usually bony and have to be discarded. In appearance the coal is lustrous, much of it iridescent, and its columnar cleavage is one of its more characteristic features. Its chemical composition and uses are indicated by the analyses given on page 24 and the descriptions given on pages 26–29.

Lower coals.—A coal 60 to 70 feet lower than the Miller bed has been opened at a few points about South Fork and Mineral Point. This coal probably corresponds with the Brookville or A coal. Most of the openings are fallen shut, but it is mined at one bank at South Fork to supply the local brick company. It is better known locally as the "6-foot coal," or "dirty A," but where seen measured only 3½ feet of coal, as indicated in the section below:

Section of Brookville (A) coal at South Fork.

	Ft.	in.
Shale.		
Coal	2	6
Bone		1
Coal	1	
Total coal	3	6

The analysis given on page 25 shows a large content of ash and sulphur, but fixed carbon and volatile matter about the average for coals in this quadrangle. It is possible that the coal may be valuable in this district, but the fact that it has not been developed on any extensive scale and apparently has not come into competition with the other coals of the district is strong presumptive evidence that in quality it is not up to the standard of the other coals mined about South Fork.

BLACKLICK CREEK DISTRICT.

In the territory lying along Blacklick Creek and its south fork mining operations are confined exclusively to the creek valley, the principal mining towns being Nant-y-Glo, Twin Rocks, Weber, Vintondale, and Wehrum. The production of the district was about 5,000 tons in 1894, but had increased to 1,045,802 tons, valued at $1,019,617, in 1905.

The coals along Blacklick Creek outcrop from the town of Nant-y-Glo westward to Vintondale. Just west of the latter town the highest coal that is workable disappears below drainage level and farther west, at the town of Wehrum, mining operations are conducted by means of a shaft. West of Wehrum the rise of the beds brings the coal-bearing formation above drainage level just at the west edge of the quadrangle, near Dilltown, and a few country banks have been opened on Mardis Run.

Upper Freeport coal.—In this district a coal bed of workable thickness is present about 150 feet above the Lower Kittanning coal. The interval between these two coals has been found exceptionally constant. It has been measured at Nant-y-Glo and Vintondale and reported the same at Twin Rocks by the engineer of the collieries situated at that point. At Wehrum certain of the diamond-drill records show a coal at about the same interval above the Lower Kittanning bed. A few sections of this upper coal, which is presumably the upper Freeport, are as follows:

Sections of Upper Freeport coal along Blacklick Creek.

	Roof.	Upper bench.	Parting (bone).	Lower bench.	Floor.
		Inches.	*Inches.*	*In.*	
Near Vintondale	Shale...	18	1	Coal..16 Bone . 7	Clay.
Twin Rocks	Shale...	25½	½-2	Coal..15 Bone . 6	Clay.
Ivory Hill Coal Mining Co., Nant-y-Glo	Shale...	22	2½-3	Coal..15½ Bone . 3½	Clay.

The bed has two benches, separated by a small bone parting, and the coal aggregates in thickness from 3 to 3½ feet. The presence of the parting has been a drawback to operations on this bed, but it

is quite probable that in the future the coal will be worked. If proper care is exercised in separating the thin bony parting, it should be readily marketed. The resemblance of its section to that of the Upper Freeport coal about South Fork is rather marked and it is probable that they occur at the same horizon.

Middle Kittanning coal (?).—A little more than 100 feet below this upper coal and about 50 feet above the main Blacklick bed occurs a coal which is fairly persistent. It has been called the Middle Kittanning, simply because it is the first bed above the Lower Kittanning coal. It has been seen about Twin Rocks, Nant-y-Glo, and Vintondale and at the latter point a section measured 33 inches of coal with a thin parting of shale near its base.

Lower Kittanning coal.—The next lower coal is the main bed of the Blacklick Creek district. There has been some question as to its identity. It has been regarded by some as the equivalent of the Cement bed of the Johnstown basin, and by others as the equivalent of the Miller or Lower Kittanning coal. The writer is inclined to take the latter view. Certainly the physical character of the bed, as mined along Blacklick Creek, strongly resembles the main features of the Lower Kittanning coal in the districts to the south, as the following sections will show:

Sections of Lower Kittanning coal along Blacklick Creek.

	Roof.	Main bench.	Parting.	Coal.	Parting.	Coal.	Floor.
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
Vinton Colliery Co., No. 5	Shale	42	6	12–14	.....	.....	Clay.
Pennsylvania, Beech Creek and Eastern Coal Co., No. 14.	Sandstone or shale	45	14	6	.....	.....	Clay.
Lincoln Coal Co	Sandstone or shale	45	3	0–6	.....	.....	Clay.
H. R. Dill, Dilltown	Shale	48	8	2–3	.....	.....	Clay.
Ivory Hill Coal Mining Co	Sandstone or shale	43	1½	2½	4	6	
Cardiff Coal Co	Shale	45	3	6	3	3	

The coal is made up of a main bench from 3½ to 4 feet thick. Below this there occur either one or two thinner benches, but in places both lower benches are absent. The second lower bench was not observed about South Fork or Johnstown, but is rather persistent along Blacklick Creek. Below the lowermost bench occurs a good body of clay not exploited in this district. The roof of the coal is either very firm shale or sandstone. This fact, in connection with an irregular floor, the general absence of clay veins, and the fact that it is nongaseous, are points in which it is similar to the Miller bed in the Conemaugh Valley. The coal is bright and lustrous, with a marked tendency to columnar cleavage. Analyses of this coal are given on pages 24–25.

Lower coals.—Along Blacklick Creek other coals outcrop which are below the main Blacklick bed. In the railroad cut near Twin Rocks two representatives at least of these lower coals appear, but

they are so badly broken that they are not of commercial value. Attempts to work one of these coals at Twin Rocks have resulted in failure. They are tentatively correlated with the group lying directly above the Pottsville formation.

WINDBER DISTRICT.

The Windber district includes the territory about the town of Windber situated within the Johnstown quadrangle. This district is among the more recently developed in this part of the State. It is first mentioned in the State mine inspector's report in 1897, with two mines belonging to the Berwind-White Coal Mining Company, having an annual output of about 50,000 tons. Since that year the developments have expanded rapidly, and in 1905 there were ten mines in the district, with a total annual output of more than 3,000,000 tons of coal.

All the workable coals in the district belong in the Allegheny formation, which is above drainage level in all the hills surrounding the town. Of these coals only the Lower Kittanning coal is now worked, but higher coals are known to be valuable. All the operations on the Lower Kittanning bed are controlled by the Berwind-White Coal Mining Company, and of their ten collieries two—namely, Eureka Nos. 37 and 40—are located just within the southern boundary of the quadrangle, and the underground workings of two others—Eureka Nos. 35 and 36—just touch the southeast edge.

Upper coals.—The highest of the coals outcrops in all the hills surrounding Windber. It lies about 170 to 180 feet above the Lower Kittanning coal in the hills near No. 37 mine, and this interval remains fairly constant as far east as Elton, where drillings show it to be about 175 feet. Still farther northeast, approaching South Fork of Little Conemaugh River, the interval increases to 200 feet. Little definite information regarding this coal was obtainable in this district, as no openings were located. It is, however, persistent and may be of workable thickness.

About 40 to 50 feet below the Upper Freeport coal is the Lower Freeport. It also is fairly persistent in this district, but little is known about it, except from data furnished by drillings. Some of the records from points northeast of Windber show it to be in places 3 feet thick, while others show less promising sections. It is possible that this bed may be valuable in the future, but the data obtained are insufficient to afford a basis for a positive opinion.

The Upper Kittanning or C′ coal in the Windber district lies practically midway between the Upper Freeport and Lower Kittanning beds. This is one of the valuable coals about Windber, and, though not worked commercially as yet, it promises to rival in importance the Lower Kittanning or Miller bed. It is stated in the description of this coal in the Johnstown basin (p. 32) that on Stony

Creek, south of Moxham, it increases in thickness. The unusual thickness of 5 to 6 feet prevails generally to the north of Windber, as the following sections will show:

Sections of Upper Kittanning coal north of Windber.

	Roof.	Coal.
		Ft. in.
One-half mile north of No. 37	Black shale	6
One mile north of No. 37	Black shale	5 5
One mile southeast of Walsall	Shale	4 8

The coal where measured shows a clean face, ranging from 4½ to 6 feet in thickness, with a firm shale roof. To judge from the appearance of the coal, its quality is equal to that of the coal mined from this bed about Johnstown.

Lower Kittanning coal.—The Lower Kittanning coal is worked on a large scale in all the hills about Windber, and the large operations conducted by the Berwind-White Coal Mining Company have drawn to the town between 4,000 and 5,000 employees of all classes. The coal outcrops well down in the hills about the town, enabling the operations to be conducted from the outcrop by drifts. Of the large mines now working only two are situated in the Johnstown quadrangle, namely, Eureka Nos. 37 and 40, but the character of the coal at these mines and as seen at some of the country banks to the northwest near Walsall may be regarded as typical of the coal in this district.

Sections of Lower Kittanning coal near Windber.

	Roof.	Main bench.	Parting.	Lower bench.	Floor.
		Inches.	*Inches.*	*Inches.*	
Eureka No. 37	Sandy shale	42	3-24	3-18	Clay.
Country bank, near Walsall	Sandstone	41	.....	.....	

Little need be said regarding the physical character of this coal about Windber. The above sections are typical as to the thickness of the main bench. The under coal is usually present, and in some of the mines is remarkably uniform. There is also present a small rider, averaging 3 to 4 inches in thickness and lying from 3½ to 4 feet above the main bench. In other respects the coal resembles the Lower Kittanning along Conemaugh River.

The analyses of this coal given on page 25 show its carbon content to be among the highest in the area, with a comparatively low amount of sulphur and ash. Two tests on samples selected by the operators showed an evaporative power of 9.04 and 9.79 pounds of water per pound of dry coal, thus indicating its high standing as a steam fuel.

CONEMAUGH FURNACE DISTRICT.

Along the west edge of the quadrangle, in the valley of Conemaugh River, the lower part of the Allegheny formation is brought down to drainage level by the steep dips along the western flanks of the Laurel Ridge anticline. There are two commercial mines on the Lower Kittanning coal in this district, operated by the Nineveh Coal Company and the Johnstown Coal Company. The coal at these two mines is strictly comparable in every way with the corresponding coal as mined farther east near Johnstown and South Fork. It averages about 3½ feet in thickness and has the characteristic under coal and a valuable under clay which has not been worked. Its roof is strong, and there are the usual rolls in the floor.

Higher coals exist in the hills about Cramer and in East Wheatfield Township, but little is known about them.

LIST OF MINES IN THE JOHNSTOWN QUADRANGLE.[a]

JOHNSTOWN DISTRICT.

UPPER FREEPORT (COKE YARD) COAL.

1. Cambria Steel Company, Conemaugh slope.
2. Ferndale Coal Company.
3. Berkebile Coal Company.
4. William Schaeffer.
5. William Davis.
6. William Cover.
7. Johnstown Press Brick Company.
8. Davis mine, Grubtown.
9. Lewis Epply.
10. L. J. Mitchell.
11. Charles Umbarger.

UPPER KITTANNING (CEMENT) COAL.

12. Cambria Steel Company, Rolling Mill mine.
13. Cambria Steel Company, Franklin No. 1.
14. Valley Coal and Stone Company, No. 1.
15. Valley Coal and Stone Company, No. 2.
16. Citizens' Coal Company, Eighth Ward mine.
17. Citizens' Coal Company, Dale mine.
18. Suppes Coal Company, No. 1.
19. Suppes Coal Company, Dale mine.
20. Sunnyside Coal Company, No. 2.
21. Llewellyn mine.
22. Highland Coal and Coke Company.
23. Caddy Coal Company.
24. Caufield mine.
25. Fyock mine.
26. Livergood mine.
27. Jacoby mine.
28. Wertz & Miller.
29. Edward Litsinger.
30. George Heidingsfelder.
31. John F. Griffith.
32. J. J. Orris.
33. Lewis Prosser.
34. E. W. Fuge.
35. Samuel Fuge.
36. Kelso Smokeless Coal Company.

LOWER KITTANNING (MILLER) COAL.

37. W. J. Williams, Kernville slope.
38. W. J. Williams, Morrellville mine.
39. Cambria Steel Company, Franklin slope, No. 2.
40. Citizens' Coal Company, Green Hill slope.
41. A. J. Hawes & Sons (Limited), shaft.
42. A. J. Hawes & Sons (Limited), Coopersdale mine.
43. Keystone Coal Company, Conemaugh mine.
44. Robertson & Griffith.
45. Ingleside Coal Company.
46. John Adams.
47. J. L. Custer.

SOUTH FORK DISTRICT.

UPPER FREEPORT (LEMON) COAL.

48. Pennsylvania, Beech Creek and Eastern Coal Company, No. 8.
49. South Fork Coal Company, No. 2.
50. H. C. Stineman, No. 5.
51. O. M. Stineman, No. 3.

UPPER KITTANNING (CEMENT) COAL.

52. H. C. Stineman, No. 6.
53. O. M. Stineman, No. 3½.
54. Charles Hutzel.
55. Robert A. Giles.
56. H. W. Gillan.

[a] See Pt. II.

LOWER KITTANNING (MILLER) COAL.

57. South Fork Coal Company, No. 1.
58. Priscilla Coal Company.
59. Pennsylvania, Beech Creek and Eastern Coal Company, No. 3.
60. Pennsylvania, Beech Creek and Eastern Coal Company, No. 5.
60a. Pennsylvania, Beech Creek and Eastern Coal Company, shaft.
61. Argyle Coal Company, Argyle No. 1.
62. Argyle Coal Company, Argyle No. 2.
63. Argyle Coal Company, Argyle No. 3.
64. Stineman Coal and Coke Company, No. 2.
65. Stineman Coal and Coke Company, No. 4.
66. Stineman Coal Mining Company, No. 1.
67. Page-Reighard Mining Company, Juniper mine.
68. Valley Smokeless, No. 3 (Radnor mine).

BROOKVILLE (?) ("DIRTY A") COAL.

69. J. H. Wickes (omitted on map owing to lack of space).

BLACKLICK CREEK DISTRICT.

UPPER FREEPORT COAL.

70. Ivory Hill Coal Mining Company.

LOWER KITTANNING (MILLER) COAL.

71. Ivory Hill Coal Mining Company.
72. Lincoln Coal Company.
73. Pennsylvania, Beech Creek and Eastern Coal Company, No. 14.
74. Nant-y-Glo Coal Mining Company.
75. Cardiff Coal Company.
76. Blacklick Coal Mining Company, Colliery No. 2.
77. Big Bend Coal Mining Company, Nonpareil No. 1.
78. Commercial Coal Mining Company, No. 3.
79. Commercial Coal Mining Company, No. 4.
80. Vinton Colliery Company, No. 5.
81. Vinton Colliery Company, No. 3.
82. Vinton Colliery Company, No. 2.
83. Vinton Colliery Company, No. 1.
84. Vinton Colliery Company, No. 6.
85. Lackawanna Coal and Coke Company, No. 4.
86. Amos Rager.
87. H. R. Dill.

WINDBER DISTRICT.[a]

LOWER KITTANNING (MILLER) COAL.

88. Berwind-White Coal Mining Company, Eureka No. 37.
89. Berwind-White Coal Mining Company, Eureka No. 40.

CONEMAUGH FURNACE DISTRICT.

LOWER KITTANNING (MILLER) COAL.

90. Johnstown Coal Company, Cramer mine.
91. Nineveh Coal Company.

[a] Only those mines which lie in the Johnstown quadrangle are given.

THE ELKHORN COAL FIELD, KENTUCKY.

By Ralph W. Stone.

INTRODUCTION.

For many years the region around the heads of Elkhorn and Shelby creeks and of Boone Fork in Pike and Letcher counties, Ky., has had a good reputation among investors as a source of coal in great quantity and of excellent quality. In order to make this field available, a branch of the Chesapeake and Ohio Railway was extended into Pike County in 1906, and mines were opened at once on Marrowbone Creek, about 20 miles above Pikeville. Because of the prospective importance of the region, a reconnaissance survey of the coal field lying in the drainage basin of Russell Fork of Big Sandy River was undertaken by the Geological Survey. The area covered by this survey is triangular in shape, having its base along Pine Mountain from Pound Gap to Grassy Creek, and its apex at Millard.

Very little has been published concerning the resources of this district, the descriptions in reports of the Kentucky Geological Survey and of the State inspector of mines aggregating only a few pages. Detailed maps of the region furnished by the Big Sandy Company and the Northern Coal and Coke Company were compiled to make the accompanying map (Pl. III). The outlines of the coal outcrops shown are mostly the work of E. V. d'Invilliers, who prepared an extensive report on this field for the Big Sandy Company. All sections given herewith were measured by the writer.

TOPOGRAPHY.

The topography of this region is rugged, almost mountainous. The elevation of the main streams is between 700 and 900 feet, while the summits of the ridges are over 1,500 feet above tide. Between the heads of Shelby and Elkhorn creeks an area known as the Flatwoods exceeds 2,500 feet in elevation, and the crest of Pine Mountain, which marks the southern boundary of the field, averages 3,000 feet high.

The valleys are narrow and steep walled, rising abruptly several hundred feet to narrow ridge tops. There is practically no level land except the narrow valley floors, to which settlement is confined.

The area here described is divided into two unequal parts by Russell Fork, which enters Kentucky around the north end of Pine Moun-

tain, through "The Breaks." The elevation of the river at the State line is about 900 feet, and at Millard 680 feet. This difference of 220 feet in 14½ miles gives an average fall of a little more than 15 feet to the mile. The principal tributaries on the east are Powell Creek, Road Creek, and Ferrell, Beaver, and Grassy creeks, and on the west Marrowbone, Pond, and Elkhorn creeks. Marrowbone Creek has a fall of less than 50 feet to the mile in the lower 6 miles of its course; Elkhorn Creek falls 760 feet from head to mouth, an average of 38 feet for 20 miles.

ACCESSIBILITY.

Pine Mountain, which limits the coal field on the east, has been a barrier to ready access from Virginia. There are no low gaps in the ridge, and The Breaks, at the north end of the mountain, through which the river flows, is an impassable box canyon 1,000 feet deep. Practically all approach to the region, therefore, is from the north, by way of the valley of Big Sandy River.

Until 1906 Pike County was accessible only by wagon, except at infrequent intervals when flood stages made it possible for steamers to ascend the river to Pikeville. Wagon roads are few and follow only the main streams. In June, 1906, the Big Sandy branch of the Chesapeake and Ohio Railway was completed from Pikeville to Elkhorn City (Praise post-office), at the mouth of Elkhorn Creek, 21 miles above Pikeville, and to Hellier, near the head of Marrowbone Creek. The completion of the railroad brought about the opening of several mines and also increased interest in the field.

HISTORY OF DEVELOPMENT.

Small coal banks were opened in this field during the civil war, to get fuel for blacksmithing and for locomotives used in logging, but the heavily forested condition of the whole region makes wood so cheap that there has been little or no incentive on the part of the native population to develop or use the coal, which in many places is at their very doors. About 1885 capitalists began buying up blocks of coal land, partly for development and partly for speculative purposes. The control of much of this land has lately come into the hands of three companies, and in 1906 five mines, the first in the field, were opened by lessees of the Big Sandy Company, namely, the Greenough, Henry Clay, Edgewater, Marrowbone, and Pike Coal and Coke companies. Development commenced early in the year, and regular shipments of coal began in July.

All these mines are using the room and pillar system, and the coal is shot from the solid. At present ventilation is by furnace, and haulage by mules. Natural drainage is obtained. The capacity of the mines (January, 1907) is about a thousand tons daily, but the difficulty of getting cars retards delivery.

GENERAL GEOLOGY.

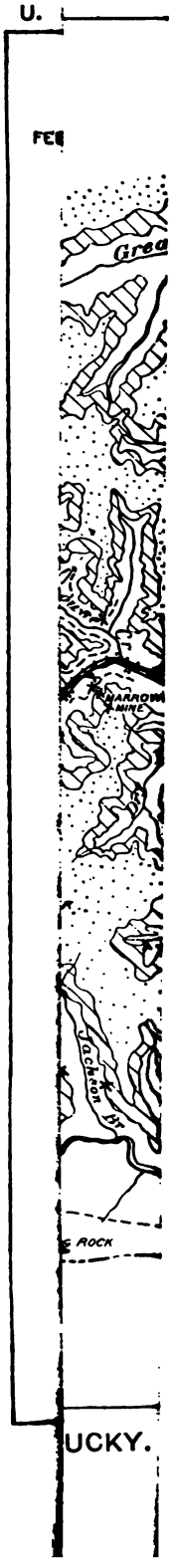
STRATIGRAPHY.

The formations exposed in this field are the Newman limestone, Pennington shale, Lee conglomerate, and a series of strata more than 1,500 feet thick carrying numerous beds of coal. The Newman limestone and the Pennington shale are several hundred feet thick and are exposed only on the west flank and crest of Pine Mountain, east of the fault which terminates the Kentucky coal field in this locality. The Lee conglomerate, which lies above the Pennington shale, is at least 1,000 feet thick. It is so elevated by the fault that its base lies along the crest of Pine Mountain, and it forms the east flank of the mountain in Virginia. The Lee makes the walls of the canyon at The Breaks, in which the fault is plainly shown. East of the fault, at the mouth of Grassy Creek, the top of the Lee is at least 700 feet above water; west of the fault it is only about 100 feet. The westerly dip of the rocks brings the top of the Lee to water level a little below Elkhorn City. This formation is composed largely of coarse, massive sandstone and fine conglomerate carrying white quartz pebbles. It contains some shale beds and may carry one or two small coal beds.

The coal-bearing rocks, which are from 1,500 to 2,000 feet thick, are composed of sandstones, shales, and coal beds. The sandstones and shales range from massive to thin bedded and from coarse to fine grained. There are no limestones in the section. The generalized section, omitting all details, is as follows:

Section of coal-bearing rocks in Elkhorn field, Kentucky.

	Feet.
Coal	4
Interval	530
Coal, Flatwoods	18
Interval	550
Coal, Upper Elkhorn	6 (4–8)
Interval	180
Coal, Lower Elkhorn	4
Interval	170
Coal, Bingham	2½
Interval	150
Coal, Millard	2
Interval	160
Coal, Auxier	3
Interval	185
Coal, Elswick	2½
Interval	75
Conglomerate, Lee.	
	2,042



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STRUCTURE.

The Elkhorn coal field is bounded on the south by the Pine Mountain fault, which parallels the crest of the mountain. This fault causes a displacement of 2,000 feet in the vicinity of Pound Gap, but to the northeast, on Grassy Creek, it decreases rapidly and probably becomes an anticlinal fold. So far as observed, there are no other faults in the field. The coal beds, which originally were deposited in a flat position, now have a slight and general tilt to the northwest. The dip is not continuous, however, but is formed of a series of low, gentle folds or waves in the strata. The dip in few places exceeds 125 feet to the mile, and in most of the area it is still more gentle. A basin, or syncline, extends from the head of Cassell Fork in a north-northwest direction to Daniels Creek, and parallel with it there is a fold or anticline that can be traced easily from Shelby Gap to the head of Wolfpit Fork. The relation of Marrowbone Creek to this anticline is such as to facilitate mining operations on both sides of the creek, giving natural drainage and easy grade for haulage in the mines. On Elkhorn Creek the relation of the structure to the outcrop is for the most part less favorable.

ECONOMIC GEOLOGY.

COAL BEDS.

Under this heading is given, in ascending order, a brief description of the stratigraphic position and extent of each of the coal beds.

Elswick coal.—From 50 to 75 feet above the top of the Lee conglomerate is a coal bed which averages 30 inches in thickness and is known locally as the Elswick coal. This bed, being the lowest, has the shortest outcrop of any in the field. It rises above the waters of Russell Fork at the mouth of Little Creek, about a mile below Elkhorn City, and keeps above the river to Grassy Creek, a distance of 4 miles. It passes below the level of Elkhorn Creek between the mouths of Big Branch and Pond Branch 1 mile above Elkhorn City.

Auxier coal.—At a distance of 250 feet above the Lee conglomerate is the Auxier coal, which usually rests upon a 30-foot bed of massive sandstone. The coal bed ranges in thickness from 18 to 54 inches, with an average of 33 inches. It rises above the bed of Russell Fork at the mouth of Biggs Branch and can be found from that point to Trace Fork of Grassy Creek. It goes below the level of Elkhorn Creek a few rods below the mouth of Kettlecamp Creek.

Millard coal.—This coal is 400 feet above the base of the coal-bearing rocks, and because it has been opened at a number of places near Millard post-office, it is given this name to facilitate description. The bed has an average thickness of 3 feet, but includes several part-

ings. It has been prospected in each of the eastern tributaries of Russell Fork from Powell Creek to Ferrell Creek. There is a good opening on this coal near the tipple of the Marrowbone mine, about 60 feet above creek level, and at Coleman's, opposite Marrowbone station.

Bingham coal.—This coal is 590 feet above the top of the Lee conglomerate and 180 feet below the Lower Elkhorn coal. It was first noted at E. B. Bingham's, on Ferrell Creek, where a prospect is reported to have shown the bed 30 inches thick. It was discovered also under the incline at the Marrowbone mine. In four sections of the bed it was found to range from 30 to 53 inches in thickness.

Lower Elkhorn coal.—This bed has been thoroughly prospected throughout the field, and its location is well known. It is from 750 to 800 feet above the Lee conglomerate, and usually overlies a more or less massive sandstone. It will be seen by the accompanying map (Pl. III) that the Lower Elkhorn coal outcrop delineates every valley and is found throughout the field, except on the south side of Elkhorn Creek. It is everywhere of workable thickness, averaging more than 4 feet. Its value for commercial mining, however, is greatly reduced by the fact that commonly at least one-quarter of the bed is laminated coal—that is, coal so crushed that it breaks into small chips when mined. Many of the chips are slickensided or have smooth, polished surfaces. Schistosity may be developed in the laminated coal, parallel or oblique to the normal bedding, and in some places this coal is rolled and twisted into a rumpled mass which is strikingly different from a normal bed of bituminous coal. It ignites quickly and burns readily under a strong draft, but it is high in ash, and for that reason, and also because it breaks down to slack on handling, it does not meet with a ready sale, and consequently is more or less of a loss to the operator. The laminated coal usually forms the upper part of the bed, but it may be in the middle and overlain by solid block coal. It appears to have been produced by crushing between laterally moving surfaces, and in that respect resembles the Widow Kennedy coal bed at Dante and other places in Virginia.

Upper Elkhorn coal.—This bed is from 160 to 190 feet above the Lower Elkhorn, or 900 to 1,000 feet above the Lee conglomerate. Geographically it is located in the high land, being from 700 to 900 feet above Russell Fork, and therefore near the tops of the ridges. It can be found throughout the entire region where the hills are high enough.

East of Russell Fork, in the vicinity of Ferrell Creek, the Upper Elkhorn coal ranges from 5 to 7 feet in thickness, with only 4 to 8 inches of waste. On Marrowbone Creek the average thickness is 3 feet 10 inches, and 3 feet 2 inches of this is marketable. At the head of Elkhorn Creek, where the bed attains an extraordinary development, the thickness of the entire bed ranges from 7 feet 8 inches to 9 feet

4 inches, with an average of 8 feet 7 inches. The amount of marketable coal in this bed, around the head of Elkhorn Creek, averages 7 feet 9 inches.

Flatwoods coal.—The Flatwoods coal is approximately 1,500 feet above the Lee conglomerate. It occupies only two small areas of the greatest elevation in the field. The larger area lies between the heads of Shelby, Elkhorn, and Marrowbone creeks, and the smaller is at the head of Poorbottom Creek. The thickness of the bed ranges from 14 to 18 feet, but only the upper 7 feet of it can be mined advantageously.

Higher coal.—Nothing is known of any coals higher in the section except a 4-foot bed which is reported in a few hills on the top of the Flatwoods area, more than 500 feet above the Flatwoods coal.

DISTRIBUTION OF THE COALS.

The occurrence of the coals in this region will be described briefly, with only sufficient detail to give a general idea of the field. The description of the coals is arranged by creek valleys, beginning with the left or east side of Russell Fork.

Powell Creek.—In the vicinity of Millard post-office and on Powell Creek the Millard coal has been opened in a number of places, in less than half of which the coal is now exposed. It ranges in thickness from 1 foot 6 inches to 2 feet 4 inches, and can be seen at an opening near the schoolhouse below Powell Creek. The Bingham coal shows a thickness of 3 feet in a drift near Hunter's, on Powell Creek. The Lower Elkhorn coal is exposed in pits on Mead Fork and on the main stream three-fourths of a mile above Widow Mead's. It is composed of two benches, the lower consisting of 2 feet of solid coal and the upper of 15 inches of laminated coal. The Upper Elkhorn is present at the head of the creek, where it is about 3 feet thick.

Biggs Branch.—One mile up Biggs Branch the Millard coal has been dug near creek level, and shows a bed 1 foot 9 inches thick. Near Isaac Lee's, at the forks 2 miles up the creek, the Lower Elkhorn is a doubled bed having the following section:

Section of Lower Elkhorn coal on Biggs Branch.

	Ft.	In.
Coal, soft, dirty	1	4
Coal, block	2	2
Shale	6	
Coal, solid	2	
Coal, bony	2	3
	13	9

Higher coals ranging from 2 feet 6 inches to 5 feet in thickness occur on the opposite hillside.

Daniels Creek.—The Millard coal opened by Mose Coleman on the right fork of Daniels Creek is 21 inches thick, and the Lower Elkhorn opened by Elijah Anderson at the head of the left fork is more than 4 feet thick, with 12 inches of laminated coal at the top.

Harless Creek.—The lowest coal on Harless Creek is the Auxier, which was mined at the mouth of Lower Lick thirty years ago to provide fuel for a locomotive hauling saw logs. This bed is 5 feet thick, but contains 18 inches of shale. A quarter of a mile below Harless Creek, at H. E. Coleman's, the Millard coal has been mined for ten years to supply a few families. The bed is 4 feet 4 inches thick, and is divided into three benches by 10 inches of clay and 4 inches of bone. Four openings on the Lower Elkhorn were seen on Harless Creek. It is 5 feet thick on Lower Lick, 3 feet 3 inches in Corn Hollow and Mose Coleman Hollow, and 5 feet 3 inches at David Coleman's, on Right Hand Fork. The upper part, 1 foot 3 inches thick, is laminated. The Upper Elkhorn in Mose Coleman Hollow is a 5-foot bed with one thick parting.

Jimmie Creek.—The Millard coal shows unusual thickness at an opening 1¼ miles up Jimmie Creek. The bed measures 4 feet 4 inches, but is so broken by bone and clay bands as to be practically valueless. The Elkhorn coals have not been prospected in this creek.

Road Creek.—The Auxier coal is 3 feet thick at Joe Looney's, 1 mile up Road Creek, and the Millard coal near the mouth of Isam Fork and at the mouth of Middle Fork has a thickness of 2 feet 2 inches, including 3 inches of clay. Pits on the Lower Elkhorn coal have been opened in Coalbank Hollow, Cotton Patch Hollow, Middle Fork, and Isam Fork. Robert Martin's bank near the mouth of Road Creek has the typical section of 1 foot 3 inches laminated coal and 4 feet 1 inch of solid coal. The Lower Elkhorn ranges in thickness from 5 feet to 5 feet 10 inches, but the upper part, 1 foot 3 inches thick, is laminated. No openings were seen on the Upper Elkhorn coal.

Ferrell Creek.—The Auxier coal at the schoolhouse below Sprucepine Creek is 1 foot 10 inches to 2 feet thick, and on Board Fork and Shop Branch, above Ferrell Creek, it is reported to be 3 feet thick. The Millard coal is 2 feet thick in the first hollow on the left above Belcher's store at the mouth of Ferrell Creek, 2 feet 6 inches in Hoggston Hollow, and 1 foot 10 inches at water level at the mouth of Bingham Fork. The Bingham coal is reported to be 2 feet 6 inches thick at water level half a mile up Bingham Fork. The Lower Elkhorn in Middle Field Fork is a bed consisting of 1 foot 2 inches of laminated coal and 3 feet 11 inches of solid coal. On Sprucepine Creek the same bed is 8 feet 4½ inches thick, but it includes a 20-inch clay seam. It is 5 feet 9 inches thick at the

head of the creek, near Richard Epling's, and in several openings on Abner Fork it is more than 6 feet thick, including about 15 inches of laminated coal and 3 to 6 inches of clay. Two openings on the Upper Elkhorn show 6 feet 3 inches and 7 feet of coal, with scarcely any parting.

Beaver Creek.—The Elswick coal is exposed at the schoolhouse near the mouth of Beaver Creek. It is in two benches, the upper one carrying 2 feet 4 inches to 2 feet 6 inches of coal and the lower one 7 inches, with an 8 to 9 inch shale parting between them. The Auxier coal is 3 feet thick on this creek. The Lower Elkhorn was not seen here, but is reported from 2 to 6 feet thick. The Upper Elkhorn was seen only at Miles Potter's, at the head of Left Fork, where it is a 6-foot 9-inch bed, with less than 2 inches of partings.

Grassy Creek.—The bloom of the Elswick coal occurs in the road north of Big Hollow. The Auxier coal opened near Riley Cavin's, on Trace Fork, is 1 foot 8 inches thick, and on the right side of Abes Fork 2 feet 6 inches thick. A coal bed opened by the Yellow Poplar Company on the right of Abes Fork, near Old House Branch, ranges in three openings from 4 feet 2 inches to 6 feet in thickness, and carries one 7-inch clay band. These openings are close to the Pine Mountain fault. Coal supposed to be the Millard, prospected at the foot of Greasy Spur, 1½ miles up Trace Fork, is 5 feet 8 inches to 6 feet 1 inch thick, with 15 inches of clay in three partings. A 3-foot bed of coal, found 200 feet higher in the hill, is probably the Bingham coal. The only opening on the Elkhorn coals on Grassy Creek is at the head of Trace Fork, and is reported to show the Lower Elkhorn 4 feet 10 inches thick.

Marrowbone Creek.—The Auxier coal is insignificant on Marrowbone Creek, as can be seen by an outcrop at Marrowbone station.

The Millard coal is 240 feet above the railroad at the mouth of the creek, where it is 2 feet 6 inches thick. It maintains this thickness at John Coleman's, on Wolfpit Fork, and at Dan Stewart's, in Laurel Hollow. In a pit 370 feet below the Lower Elkhorn coal at the Marrowbone mine, this bed shows 2 feet 4 inches of coal, and on Rockhouse Creek it varies from 2 feet 2 inches to 2 feet 6 inches.

The Bingham coal is exposed under the incline at the Marrowbone mine, 190 feet below the Lower Elkhorn. It consists of a lower bench 2 feet 9 inches thick, overlain by 1 foot 2 inches of clay, and an upper bench of 6 inches of coal. At Alec Ratliff's, on Wolfpit Fork, it is 2 feet 6 inches thick.

The Lower Elkhorn coal at the heads of Wolfpit Fork and of Deadening Fork of Rockhouse Creek consists of 3 feet to 3 feet 4 inches of solid coal, overlain by 4 to 9 inches of bony coal. The bed has no partings and no laminated coal, as is usual elsewhere. In the five mines on Marrowbone Creek and in numerous other openings the

Lower Elkhorn consists typically of 2 feet 6 inches to 3 feet of solid coal, overlain by 1 foot to 1 foot 8 inches of laminated coal. At a few places the laminated coal is thin and overlain by several inches of solid coal.

The Upper Elkhorn bed is opened at a number of places on this creek, and shows thicknesses ranging from 3 to 5 feet, with the upper 5 to 10 inches laminated. A notable exception is the occurrence at the Marrowbone mine, where the bed is 3 feet 10 inches thick, but includes a clay parting 1 foot 5 inches thick near the bottom.

The Flatwoods coal is shown by three trenches near the head of Cassell Fork to be from 14 feet to 18 feet 9 inches thick. Two-thirds of the bed is practically worthless, on account of clay partings.

Pond Creek.—The Lower Elkhorn coal has been opened by Sanford Moore, N. A. Ramey, William Ramey, and Grant Hawkins, and at each pit shows approximately 3 feet of solid coal, overlain by 1 foot of laminated coal.

Jesse Creek.—The Lower Elkhorn coal has been dug in a hollow off Left Branch of Jesse Creek above Frank Owen's house, and shows the same character as on Pond Creek, being 4 feet thick with the upper part laminated.

Little Creek and Moore Branch.—The Elswick coal is 3 feet to 3 feet 4 inches thick along the railroad below the mouth of Moore Branch. The Auxier coal is 3 feet 8 inches thick on Little Creek, and 3 feet 1 inch in the hollow back of Calvin Ramey's, half a mile farther down the river. At Moore Branch the Auxier is thicker than elsewhere in the field, measuring 4 feet 6 inches with a 2-inch clay parting near the floor.

Elkhorn Creek.—The Elswick coal is dug in two or three places within a mile of Praise and shows from 2 feet 6 inches to 2 feet 9 inches of coal.

The outcrop of the Auxier was traced by its bloom to the point where the coal falls below creek level near the mouth of Kettlecamp Creek, but a section of the bed was not obtained.

The Lower Elkhorn coal is a little over 4 feet thick at Jackson Branch, but the upper third or half is laminated. Near the head of Ashcamp Branch the bed is composed of 10 inches of solid coal, 9 inches of laminated coal, and a main bench of solid coal at least 2 feet 6 inches thick. An opening at Harry Bentley's, below Pigeon Creek, shows a 4-foot bed, only the upper 2 inches being laminated; but at the Childers opening on Big Branch there is 2 feet 6 inches of laminated coal and only 13 inches of solid coal. On Shop Branch and at the head of Shelby Creek the Lower Elkhorn is 3 to 4 feet thick, and has from 12 to 20 inches of laminated coal in the middle instead of at the top of the bed. At J. D. Bentley's and at Esau Moore's, on Elkhorn Creek between Shelby Gap and Marshall Branch; at William

Isom's, on Marshall Branch; and at the mouth of Peaks Branch, the Lower Elkhorn bed has a thickness of 3 feet. In each place the lower half of the bed is solid coal and the upper half ranges from 7 to 13 inches of laminated coal, overlain by 6 to 10 inches of solid coal.

The Upper Elkhorn coal is 2 feet 10 inches thick at Ashcamp Gap, and on the longest fork of Pigeon Creek it is 3 feet 3 inches thick, including 4 inches of laminated coal. On Marshall Branch the Upper Elkhorn begins to assume the proportions that have made it famous in this region. At the head of the right fork 4 feet 3 inches of coal is seen in two benches, separated by 14 inches of shale; while in two openings at the head of the left fork the bed is 8 feet and 8 feet 9 inches thick, and contains only from 4 to 9 inches of partings. On Peaks Branch the bed is at least 10 feet thick, with one 10-inch parting. On Bens Branch the Upper Elkhorn measures 8 feet 10 inches, with a 10-inch parting in the middle, and on Joes Branch 9 feet 1½ inches, with only a 2½-inch parting. The Mullins opening at the head of Elkhorn Creek shows this bed 7 feet 7 inches thick, with 3 inches of clay in the middle. The coal bed maintains an average thickness of 8 feet over a large area around the heads of Boone Fork of Kentucky River and of Shelby Creek.

Coal has been found in several places on the flank of Pine Mountain. A bed on William Potter's land above Joes Branch is reported 9 feet 6 inches thick. Ten feet of clean, solid coal outcrops 1 mile up Pigeonroost Creek, and a bed 9 feet thick is reported on the road to Blowing Rock Gap.

SUMMARY.

It will be seen from the foregoing description of the field that it contains six coal beds which are of workable thickness. Two or three other beds are of unknown thickness. The following table shows the range in thickness of the workable beds:

Thickness of workable beds in Elkhorn field, Kentucky.

Coal bed.	Number of sections.	Maximum.	Minimum.	Average.
		Ft. in.	*Ft. in.*	*Ft. in.*
Elswick	5	3 10	2 6	3 1
Auxier	8	4 11	1 8	3 1
Millard	20	4 4	1 6	2 5
Bingham	4	4 5	2 6	3 1
Lower Elkhorn	34	6 11	2 9	4 3
Upper Elkhorn	17	8 10	3 3	5 2

It should be borne in mind that this table is based on the total thickness of the beds, and does not represent the amount of marketable coal contained in each bed, which is considerably less than these figures.

ANALYSES OF COAL.

Few bituminous coals in the Appalachian field are of higher grade than those described in this report. The following table shows the chemical character as determined at the United States Geological Survey fuel-testing plant at St. Louis, from mine samples taken by the writer:

Analyses of coal samples from Elkhorn field, Kentucky.

[F. M. Stanton, analyst.]

	Millard.	Lower Elkhorn.					Upper Elkhorn.		Flatwoods.
Laboratory No.	3662.	3705.	3706.	3702.	3663.	3661.	3708.	3828.	3829.
Analysis of sample as received:									
Moisture	3.00	2.90	3.35	3.19	4.73	5.27	4.03	3.96	3.45
Volatile matter	32.22	28.59	31.76	25.83	31.62	27.74	32.46	32.37	33.69
Fixed carbon	56.59	53.70	60.81	48.61	61.57	59.75	58.73	61.10	54.61
Ash	8.19	14.81	4.08	22.37	2.08	7.24	4.78	2.57	8.25
Sulphur	1.06	.49	.54	.40	.71	.50	.74	.56	.82
Loss of moisture on air drying	1.40	1.30	1.70	1.80	3.20	3.40	2.80	1.90	1.70
Analysis of air-dried sample:									
Moisture	1.62	1.62	1.68	1.42	1.58	1.93	1.26	2.10	1.78
Volatile matter	32.68	28.97	32.31	26.30	32.66	28.72	33.40	33.00	34.27
Fixed carbon	57.39	54.41	61.86	49.50	63.61	61.85	60.42	62.28	55.55
Ash	8.31	15.00	4.15	22.78	2.15	7.50	4.92	2.62	8.40
Sulphur	1.07	.50	.55	.41	.73	.52	.76	.57	.83

The following table contains analyses of samples taken by E. V. d'Invilliers for a private report:

Analyses of coals in the Elkhorn field, Kentucky.

[A. S. McCreath, analyst.]

Coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.
Elswick [a]	0.65	30.55	59.239	8.18	1.381	.....
Auxier [b]	.65	29.96	58.98	9.72	.69	.....
Lower Elkhorn [c]	1.441	31.804	56.837	9.538	.558	0.0028
Upper Elkhorn [d]	1.538	34.985	58.367	4.499	.587	.0022

[a] Mouth of Moore Branch.
[b] Mouth of Elkhorn Creek.
[c] Average of 9 samples from entire field.
[d] Average of 19 samples from entire field.

The following table is given for the purpose of comparing the Elkhorn coals with well-known eastern bituminous coals:

Average analyses of eastern bituminous coals.

	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
Pocahontas, semibituminous (average of 38) [a]	0.73	17.43	77.71	4.63	0.62
New River (Quinnemont), semibituminous (average of 17) [b]	.60	19.93	75.20	4.27	.67
Pittsburg (Connellsville), coking (average of 20) [c]	1.130	29.812	60.420	7.949	.689
Lower Elkhorn (average of 22)	1.425	32.105	58.435	7.459	.574
Upper Elkhorn (average of 19)	1.538	34.985	58.367	4.499	.587
Clinch Valley gas coal [d]	1.180	37.398	56.732	5.602	.619
Westmoreland gas coal [d]	1.427	37.521	54.921	5.418	.713
Pennsylvania gas coal [d]	1.280	38.105	54.383	5.440	.792

[a] White, I. C., Geol. Survey West Virginia, vol. 2, 1903, pp. 695, 696, 700.
[b] White, I. C., op. cit., p. 670.
[c] H. C. Frick Coke Company.
[d] McCreath, A. S., and D'Invilliers, E. V., Mineral Resources of Upper Cumberland Valley, 1888, p. 145.

COKE.

Analyses and tests of coke made at several different laboratories and plants for the Northern Coal and Coke Company show that the Upper Elkhorn coal around the head of Elkhorn Creek is an excellent coking coal. The coke produced from it is equal to the standard cokes made in this country to-day and is superior to some in its very low percentage of sulphur and phosphorus.

Analyses of five samples of 48-hour coke and four samples of 72-hour coke made from coal taken from the Ben Potter and William Mullins banks in beehive ovens built by the Northern Coal and Coke Company, on Elkhorn Creek, average as follows:

Analyses of Elkhorn coke.

[A. S. McCreath, analyst.]

	48-hour.	72-hour.
Moisture	0.187	0.151
Volatile matter	1.265	1.147
Fixed carbon	90.140	91.072
Ash	7.891	7.082
Sulphur	.517	.546

Phosphorus to the amount of 0.003 per cent was found in two samples.

A sample of 48-hour coke from the coal at Ben Potter's gave the following results in a physical test by John Fulton, of Johnstown, Pa.:

Physical test of Elkhorn coke.

Percentage by volume of coke	59.84
Percentage by volume of cells	40.26
Compressive strength of cubic inch, one-fourth ultimate strength.....lbs..	279
Height of furnace charge without crushing.....feet..	111
Order in cellular space	1.25
Hardness	2.95
Specific gravity	1.75

TONNAGE.

Any estimate of the amount of coal in this field necessarily is only approximate. It is not known absolutely how far the beds extend beneath the surface or whether the average thicknesses shown in the outcrops are maintained for any distance under cover. It is assumed that a bed 2 feet thick is workable, because beds carrying less than 2 feet of good bituminous coal are being mined in the United States to-day.

The tonnage of the Elswick and Bingham coals is estimated on an area only one-quarter that of the field, because so little is known of the character of these beds. The Auxier and Millard beds are better known and are assumed to be of workable thickness under at least 50

square miles of the 130 which constitute the field. The acreage of the Elkhorn and Flatwoods coals was obtained by planimeter from the accompanying map, the divide at the head of Russell Fork drainage being taken for the boundary of the field.

The subjoined figures are an estimate of the coal now in the ground. They do not include the 3- or 4-foot bed said to occur above the Upper Elkhorn coal or the 4-foot bed 500 feet above the Flatwoods coal. This estimate is based on a specific gravity of 1.3, or 1,800 tons per acre for every foot of coal.

Estimated gross tonnage in Elkhorn coal field, Kentucky.

Coal.	Area.	Thickness.	Amount.
	Sq. miles.	*Feet.*	*Short tons.*
Elswick	30	2½	86,400,000
Auxier	50	2½	144,000,000
Millard	50	2	115,200,000
Bingham	30	3	103,680,000
Lower Elkhorn:	*Acres.*		
East of Russell Fork	12,140	5	109,260,000
Russell Fork to Shelby Gap	33,825	4	243,540,000
Shelby Gap to head of Elkhorn Creek	9,150	3	49,410,000
Upper Elkhorn:			
East of Russell Fork	4,000	6	43,200,000
Russell Fork to Shelby Gap	20,720	3½	130,536,000
Shelby Gap to head of Elkhorn Creek	6,425	8	92,520,000
Flatwoods	2,300	7	28,980,000
			1,146,726,000

These figures are so inconceivable that the amount of coal estimated to be in this field can be grasped only when expressed in other terms than millions of tons. The total amount is nearly three times as much as all the coal mined in the United States in 1905. It would make a solid bed of coal 8 feet thick over the area shown on the accompanying map, or 1 foot thick over nearly 1,000 square miles. The amount of coal in the Upper Elkhorn bed between Shelby Gap and the head of Elkhorn Creek, if loaded in 40-foot coal cars carrying 40 tons each, would make a train 17,522 miles long. The total amount of coal in this field, over a billion tons, if loaded in the same way, would make a train 217,183 miles long, or eight trains extending around the world, with enough left over to make more than five solid trains reaching from New York to San Francisco. On the assumption that 30 per cent of this coal will be wasted in mining, there remains a possible output of 800,000,000 tons.

THE RUSSELL FORK COAL FIELD, VIRGINIA.

By Ralph W. Stone.

INTRODUCTION.

In Dickenson County and adjacent portions of Buchanan and Wise counties, Va., there is an area of 550 square miles in the midst of the Appalachian coal field in which the coal has not been extensively prospected and concerning which no reports have been published. The field to be described is that part of the drainage basin of Russell Fork of Big Sandy River which lies in Virginia.

Projects for the construction of a railroad through Dickenson County led to a reconnaissance survey of this field, which was made by the writer during six weeks in the fall of 1906, assisted by C. W. Dodge, jr., for two weeks.

GEOGRAPHY.

This field includes all of Dickenson County, the western part of Buchanan County, and the northern part of Wise County (Pl. IV). It is a heavily wooded, thinly populated, mountainous district. Sandy Ridge, which has a general elevation of 3,000 feet, forms the southeastern boundary of the field, and Pine Mountain, of equal elevation, on the dividing line between Virginia and Kentucky, forms the northern and western boundaries. The divide between Russell Fork and Levisa Fork is from 2,000 to 2,500 feet above sea level. The general elevation of the main streams is 1,500 feet, and the lowest point, where Russell Fork passes through The Breaks at the north end of Pine Mountain, is approximately 900 feet above tide at the State line.

For the most part the country is made up of steep-sided, narrow-topped ridges. There is no level land of any extent in this section of the State, the nearest approximation being some of the flat tops of the ridges, which may be comparatively level for a mile or more, but not over a hundred yards wide. The valley bottoms are narrow, many of them affording little more than room for a road beside the stream.

DRAINAGE.

All the drainage of the area here described passes into Kentucky through The Breaks, at the end of Pine Mountain, in the northeast corner of Dickenson County. The principal streams tributary to Russell Fork are Pound River, McClure Creek, and Fryingpan Creek. Pound River is the largest branch, rising at Black Mountain, on Stateline Spur, and flowing northeastward, parallel with Pine Mountain, for 25 miles. Cranes Nest River, a fork of Pound River, is about equal in size to the main stream.

SETTLEMENT.

The area of the Russell Fork basin in Virginia is 550 square miles, and the population probably does not exceed 10,000. Dickenson County has an area of 324 square miles and a population of 7,747. Settlements are confined to the valleys and are all very small, the only one having a population of more than 100 being the county seat, Clintwood, which numbers 255.

ACCESSIBILITY.

There is no ready access to this country except on horseback or by wagon road through some gap in the surrounding mountains. Pine Mountain, State-line Spur, and Sandy Ridge form a continuous barrier on three sides, with a general elevation of 3,000 feet, while the ridge on the fourth side is but little less of a barrier. Wagon roads are few and follow the main streams or the long, fairly level ridge tops.

The railroads nearest to the area are the Clinch Valley division of the Norfolk and Western Railway on the south, and the Big Sandy branch of the Chesapeake and Ohio Railway at Elkhorn City, Ky., on the north. The Chesapeake and Ohio branch could be extended into the region from the north through The Breaks with no great difficulty other than considerable expense. The South and Western Railway has surveyed a route from Elkhorn City to the mouth of Cranes Nest River, with a maximum compensated grade of less than 1 per cent. The proposed route which would connect the railroad at Dante with the Chesapeake and Ohio at Elkhorn City is to pass through Sandy Ridge by a long tunnel under Trammel Gap, and thence down McClure Creek. Another feasible route would be up Dump Creek, under Kisers Gap by a tunnel, and down Fryingpan Creek.

GEOLOGY.

STRATIGRAPHY.

The rocks of this field all belong to the Pottsville group of Carboniferous age. Three formations of this group are represented in whole or in part. The lowest is the Lee conglomerate. This is over-

lain by the Norton formation, which underlies the surface of the greater part of the area. The lower members of the Wise formation cap some of the high ridges which form the southern and eastern boundaries of the region. The Lee conglomerate is nearly 1,000 feet thick, the Norton approaches 1,000 feet, and 200 or 300 feet of the Wise formation may be present, making a total stratigraphic section of about 2,400 feet.

The Lee conglomerate is composed largely of massive cross-bedded sandstone, but may contain some thin sandy or shaly beds. Two or three coal beds have been found in it at various places. The name "conglomerate" comes from the fact that some portions of the formation, particularly the top and bottom, carry considerable quantities of small white quartz pebbles. The conglomerate as a whole is coarse grained, weathers to a grayish white, and makes conspicuous ledges or strews the surface with large blocks. It is exposed along the east side of Pine Mountain and makes cliffs several hundred feet high at The Breaks. The base of the formation is seen at Pound Gap and Osborn Gap, and a dip of 25° E. carries it below the surface close to Pound River. On Russell Fork, above the mouth of Indian Creek, a massive sandstone which carries white quartz pebbles and is believed to be the top of the Lee is exposed for several miles. At the mouths of Indian and Hurricane creeks it forms cliffs nearly 100 feet high. It rises gradually to the east and keeps above water nearly to the heads of the streams. The top of the Lee, according to a hurried field correlation, is but a few feet above Council post-office on Russell Fork.

The Norton formation is a series of sandstone, shale, and coal beds having a thickness of 1,000 feet or more and lying above the Lee conglomerate. Its upper limit is the base of the Gladeville sandstone. The position of this sandstone at Dante, the only place where a complete section could be measured, is uncertain, but on the assumption that a pebble-bearing sandstone exposed in Trammel Gap is the Gladeville and that the top of a heavy sandstone found 257 feet below the surface in a drill hole at Dante is the top of the Lee, the thickness of the Norton formation is 1,060 feet.

The relative position of the coal beds in the Norton formation in this area is as follows:

Generalized section of Norton formation in Russell Fork coal field, Kentucky.

	Feet.
Sandstone, Gladeville.	
Coal	3
Interval	140
Coal	Small.
Interval	100
Coal, Upper Banner	5
Interval	100

	Feet.
Coal, Lower Banner	4
Interval	50
Coal	2
Interval	190
Coal, Widow Kennedy	6
Interval	120
Coal	Small.
Interval	140
Coal	Small.
Interval	180
Coal	3–15
Interval	10–30
Conglomerate, Lee.	

The Gladeville sandstone is massive, coarse grained, and about 100 feet thick. It is found only in the ridge tops, except at Clintwood, where a structural basin brings it down to an elevation of 1,800 feet.

The Wise formation caps the highest ridges. It is composed of sandstone, shale, and coal, like the Norton formation. Its lower portion only is exposed in this area. A coal bed lying at or near the base has a local thickness of 8 feet on Georges and Lick creeks near Clintwood.

STRUCTURE.

The rocks in this area for the most part lie comparatively flat. So far as could be discovered in a reconnaissance trip, the dip between Sandy Ridge and Cranes Nest River is generally to the north and northwest. From the crest of Pine Mountain to Pound River and along Russell Fork below the mouth of Pound River the rocks dip to the southeast at angles decreasing in intensity as the mountain is descended. The base of the Lee on the top of the mountain dips 25° SE., but near Pound River the beds at the top of the Lee dip less than 10°. These strong dips carry the conglomerate below the surface, so that little of it is found east of Pound River.

In the triangle between Pound River, Cranes Nest River, and the county line, the rocks dip toward Brush Creek, or a point on Pound River north of Clintwood. This syncline, which is parallel with the mountain, is recognized farther upstream in Wise County, where the axis seems to lie between the north and south forks of Pound River. Structurally, the lowest point in the section of Wise County included here is near Pound post-office, for the rocks dip down South Fork and Indian, Bowlecamp, and Mill creeks.

The great fault which extends along the west side of Pine Mountain in Kentucky for many miles crosses the State line near The Breaks, and on Grassy Creek is in Virginia. It makes an escarpment several hundred feet high at the mouth of Grassy Creek, but this

decreases in height to the north until on Cow Fork it is inconspicuous. It is possible that the fault terminates in a northward-plunging anticline on Levisa Fork.

Parallel faults 75 yards apart and trending N. 40° W. were found at the mouth of Pound River. The amount of displacement was not ascertained. One of these faults crosses Pound River at the dam, directly under the grist mill, and the other extends along the left bank of Russell Fork, crossing Pound River at its mouth.

A small fault causing a displacement of about 20 feet is noticeable at the ford just below Colley post-office, near the mouth of Fryingpan Creek. A possible continuation of this fault was seen on Priest Fork, a quarter of a mile from the mouth, in a cliff above John Kiser's house. In line with these two points and possibly having some relation to them is a sharp little fold at the third bend in Russell Fork above Murphy post-office.

On Russell Fork, about 1 mile above the mouth of Hurricane Creek, near Spencer Ball's house, the massive sandstone, supposed to be the top of the Lee, abruptly disappears, and shale standing at high angles is seen at the same elevation. It is believed that there is a fault at this point, and it is possible that there is a continuation of the fault on Indian Creek, a short distance below the mouth of Cany Fork.

At Haysi, a few rods both east and west of Heyter's store, exposures in the road show coals and shales standing vertical, and in the head of a ravine a short distance farther west the rocks are greatly disturbed and indicate proximity to a fault. It is possible that other minor faults or sharp folds of small extent may be found on closer investigation of the field.

COAL RESOURCES.

INTRODUCTION.

On account of the undeveloped condition of the coal resources of the region and the reconnaissance character of the survey, it is not possible in this paper to name and describe the extent of the various coal beds occurring in this field. Many of the coal outcrops are several miles apart, and in the wooded condition of the country it was impossible to carry correlation over such distances. Some idea of the character and abundance of the coals can be obtained, however, by a description of the exposures seen at prospect trenches, coal banks, and natural outcrops. The Widow Kennedy and Banner coals of the Toms Creek field in Virginia have been recognized at many points in the area.

To facilitate description, the field may be divided into four parts, equivalent to the main drainage basins. These are Russell Fork, McClure Creek, Cranes Nest River, and Pound River.

RUSSELL FORK.

The Russell Fork district includes all the tributary drainage of Russell Fork on the east, from its head to Grassy Creek at the State line, and Fryingpan and Lick creeks on the west. Most of this region is very thinly settled, and little or no prospecting has been done for coal except on Indian Creek, where there is an unusually thick bed, and on Fryingpan Creek near Bucu.

The first coal seen at the head of Russell Fork is one-third of a mile above Council post-office. It is exposed beside the road, only a few feet above the level of the creek, at an opening known as the Isaac J. Hurt bank (No. 1[a]). An entry has been driven for 100 feet and shows the bed 5½ feet thick. This includes 2 inches of clay and 30 to 36 inches of laminated coal in the middle. It has a sandstone roof and floor, and from the fact that the underlying sandstone, well exposed a few rods farther upstream, carries abundant quartz pebbles, it is concluded that this bed is on top of the Lee conglomerate.

This same coal has been opened at a number of points on Indian Creek and shows everywhere a considerable thickness. On the Van Sutherland tract, at the head of the right fork of Indian Creek, an opening (No. 2) exposes a bed 12 feet 5 inches thick. The thickest parting is 18 inches, but much of the coal is inferior. At another opening on this fork it is reported 12 feet thick, but contains two shale partings which are 22 and 33 inches thick. In Cane Gap a 30-foot drift (No. 3) shows 15 feet 4 inches of coal. The bottom bench of this section is solid coal 4 feet 10 inches thick and the remaining 10 feet contains 4 feet of clay and shale. Near Elijah Rasnick's house, below Cane Gap, a 50-foot drift (No. 4) shows a section 6 feet 2 inches thick similar to the lower part of the bed in Cane Gap.

At the head of the left fork of Cany Fork, above S. J. Tiller's house, an entry (No. 5) driven 120 feet to obtain fuel for a locomotive used in logging developed 5 feet 6 inches of fairly clean coal and left 19 inches of laminated coal in the roof. At the head of the fork (No. 6) Hiram Tiller has cleared the outcrop and exposed more than 11 feet of coal bed. Over 2 feet of this is sandy clay parting, but the upper part of the section shows 5½ feet of solid coal.

At N. B. Sutherland's (No. 7), on Cany Fork, this coal bed is 11 feet thick, and one-half mile farther downstream it is a trifle less than 8 feet. One mile above the mouth of Cany Fork the bed is 8 feet thick, but carries three partings in the middle which aggregate 17 inches of shale. The Pitzer & Lindsay opening (No. 8), below the forks of Cany, which once supplied the fuel for a logging locomotive, is reported to have shown a 14-foot bed of coal. There is a top bench of 34 inches of coal separated by 6½ feet of shale, coal, and

[a] Figures in parentheses refer to location of coal prospects on accompanying map (Pl. IV).

U. S. GEC

Flat

bone from another bench 2 feet thick. The thick partings make it of little value for mining.

No coal beds of any value were seen for several miles down Russell Fork, but it is probable that some will be discovered if the region is prospected. Among the unimportant exposures is a 22-inch coal at the mouth of Indian Creek, an 18-inch coal in the hollow back of Bee post-office, and a 17-inch coal in the gap between Abners Fork and Priest Fork. A 2-foot bed is reported near Murphy post-office, and a 15-inch coal was seen on Little Pawpaw Branch. Prospecting has revealed several coals on Fryingpan Creek in the vicinity of Bucu post-office. Among these is a 32-inch bed at the mouth of Left Fork and a 5-foot bed one-third of a mile farther upstream (No. 9) close to the road. A quarter of a mile below Bucu, in the east bank of the creek, there is an opening which shows 46 inches of coal with only a half-inch parting, and 25 feet above it there is a 20-inch bed. On the opposite side of the creek, at Z. T. Sutherland's, an opening (No. 10) shows a bed 5 feet 10 inches thick, which is peculiar in that the lower 27 inches is a mixture of clay and laminated coal standing on edge. A road opening farther downstream shows a coal reported to be 5 feet 7 inches thick which has a marked curly laminated structure.

The Upper Banner coal has been opened in the head of the hollow back of Havre Powers's, about 500 feet above the creek (No. 11). It lies under a 50-foot ledge of sandstone and is more than 6 feet thick. On the left side of the same branch another opening shows the Upper Banner nearly 7 feet thick, with less than 20 inches of clay or bone parting. The Upper Banner has also been opened (No. 12) at the head of Beech Branch of Lick Creek, on John Deel's land. The bed is only 4 feet 2 inches thick, but is fairly clean coal. On Dog Branch, half a mile above Lick Creek, a pit (No. 13) shows a highly contorted mixture of clay and coal, which is practically worthless on account of its irregularity. The appearance of the coal suggests that this may be the Widow Kennedy bed. An opening (No. 14) at T. K. Colley's, at the mouth of Duty Branch, half a mile below Birchleaf post-office, showed about 4 feet of crushed and rolled coal under a roof of badly jointed sandstone which is so treacherous that the pit can not be kept open. The general appearance of the coal suggests that this also may be the Widow Kennedy bed.

Very little prospecting has been done on Prator Creek, and only two beds of any account were seen. One of these (No. 15) is at the head of War Fork, 2½ miles above Prator post-office, 130 feet above Larkins Owen's house, and close to the top of the ridge. The opening shows a bed 4 feet 8 inches thick, containing only one-half inch of clay. This probably is the Upper Banner coal. On Greenbrier Fork, 2 miles above the mouth and 400 feet above the creek, there is an opening (No. 16), made by Albert and Wiley O'Quinn, on

a bed which is over 5 feet thick, but which has several thin partings. At the head of Greenbrier Fork there is 2 feet 5 inches of coal on Z. T. Raines's land (No. 17), and about 2 feet of coal, probably the same bed, at Joshua O'Quinn's. On the road from the mouth of McClure Creek to Jane post-office a number of coal blooms are exposed, and a 1-foot bed has been stripped on the fork of Bart Lick. On Bart Lick, 1 mile from the road, there is a 2-foot bed opened at three places below Dr. J. W. Wright's house, and at the crook of the road on the right fork of Camp Branch there is an opening on a coal bed nearly 5 feet thick, which has a 12-inch clay parting. On Hunts Creek, the main right fork of Grassy Creek, there are three openings between Jane post-office and the divide on the road to Grundy which show from 2 to 3 feet of coal. On the right of Hunts Creek, half a mile below the gap leading to Bull Creek, an opening shows 4 feet 1 inch of very clean coal.

On the branch which joins Hunts Creek from the east at Jane post-office an opening back of T. L. Owen's house shows a 35-inch bed (No. 18), containing a 7-inch parting, and another on the Stiltner farm shows a 2-foot bed. One mile above Jane, on Noah Mullens's land, coal is taken every winter from a pit containing 28 to 30 inches of coal. On the right of Abes Fork of Grassy Creek, in Old House Branch, there are three openings (No. 19), made by the Yellow Poplar Company, which show a bed from 4 to 6 feet thick, containing a 7-inch clay band near the bottom. These openings are close to the Pine Mountain fault.

McCLURE CREEK.

Back of Homade post-office, on the head of McClure Creek, Reuben Owens has faced up a coal bed (No. 20), probably the Lower Banner, and found nearly 4 feet of solid coal. Blossoms of higher coals occur in the road between Homade and Flint Gap.

At the head of Trammel Creek the Upper Banner coal has been opened on the Brooks farm (No. 21), where it is 4 feet 11 inches thick. A 1-inch sandstone parting, 21 inches below the roof, is practically the only waste in the bed. The Lower Banner coal has been opened on Laban Phillips's place (No. 22) and shows 4 feet of coal underlain by 3 inches of clay and 4 inches of bone. In the Clinchfield mine No. 2, at Dante, on the other side of Sandy Ridge, the Lower Banner coal averages about 3½ feet in thickness. A pit (No. 23) opposite the schoolhouse near the mouth of Trammel Creek shows the Widow Kennedy coal 7 feet thick, but decreasing rapidly with depth. The record of a diamond-drill hole 150 feet away shows only 1 foot of coal at this horizon.

The Grizzle opening (No. 24), at the head of Open Fork of McClure Creek, shows the Upper Banner coal nearly 7 feet thick. The middle bench, 4 feet thick, can be profitably mined, leaving 8 inches of fire clay and 11 inches of coal in the floor and 3 inches of coal in the roof,

The Milton Carico opening (No. 25) on the Upper Banner coal at the head of Middle Fork has the same partings as the Grizzle opening, but the total thickness of the bed is less, measuring from 6 feet 3 inches to 6 feet 5 inches. Three-fourths of a mile above this point the Upper Banner is less than 5 feet thick, but has thinner partings. On Coon Branch of Open Fork the Rasnick opening (No. 26) on the Upper Banner coal shows a 9-foot bed, but it contains a 35-inch fire-clay parting. The Lower Banner coal opened farther down the branch is 6 feet thick, with 30 inches of fire clay in two partings of equal thickness. The Widow Kennedy coal is reported 5 feet thick near the mouth of this branch. Three openings (No. 27) on the Widow Kennedy coal at the Rasnick mill, below Nora post-office, show a bed about 6 feet thick, but the disturbed condition of the coal makes it of questionable value.

The Upper Banner coal has been opened at the head of Caney Creek on Alec Odle's land (No. 28) by a drift 100 feet long. The bed is 8 feet 10 inches thick, and contains a number of very thin partings. At Samuel Horn's place on the head of this creek the Upper Banner has the same number of thin partings, and is 7 feet 5 inches thick. The Lower Banner coal has a thickness of 21 inches in this vicinity.

On McClure Creek, just above the mouth of Caney Creek, there are three openings close to the road, showing a coal bed believed to be the Widow Kennedy, which ranges in thickness from 2 feet 1 inch to 5 feet.

On Squirrelcamp Branch there are five openings (No. 29) on the Upper Banner coal, showing a range in thickness from 4 feet 8 inches to 6 feet 9 inches. The thickest bed includes 15 inches of shale near the top.

In the vicinity of Mill Creek the Upper Banner coal has been extensively prospected and wherever found the bed maintains the same character, having two thin fire-clay partings and a band of sandstone from 1 to 2 inches thick. Four openings on the W. J. Ring tract, three on the right fork of Mill Creek, and two near Eli Wright's on Mill Creek (No. 30) all have an average thickness of about 5 feet. The partings in the bed are so small as to offer no difficulty in the mining of this coal.

Below the mouth of Mill Creek there is an opening back of Paris Colley's house (No. 31) and another on Low Gap Branch, both of which show the same three thin partings in a bed having a thickness of a little over 5 feet. So far as learned, there are no coal openings on the lower 5 miles of McClure Creek.

CRANES NEST RIVER.

The most extensive prospecting on Cranes Nest River is at the extreme heads of Steele and Trace forks. A number of openings have been made on both sides of these forks, and the position and character of the Upper Banner coal have been thoroughly investigated.

This coal bed for the most part is in two benches which range from 1 to 2 feet in thickness, separated by 1 inch of sandstone, the average thickness of the whole bed being 3 feet.

Several openings on the right side of Steele Fork apparently have discovered only the lower bench of this coal, for the bed measures less than 2 feet thick. At a point about a mile and a quarter above the mouth of the creek, however, a prospect shows the bed 9 feet 4 inches thick, but this contains 5 feet 9 inches of shale and fire clay in two benches, making it nearly worthless for mining.

On Trace Fork of Cranes Nest River, the Upper Banner has been opened in many places, and shows thicknesses ranging from 2 to 4 feet. A sandstone parting 1 inch thick is found in all the openings about one-third of the distance below the top of the bed, and in a few places 1 inch of fire clay appears within a few inches of the roof; but these two thin partings were the only ones encountered.

So far as learned there is only one opening on Birchfield Fork, and aside from this opening the only guide to the thickness of the coal beds in this vicinity is an average section of the coal mined at Glamorgan, on the opposite side of the ridge from the head of Birchfield Fork. In this mine the bed averages 4 feet 6 inches in thickness and contains two very thin partings, but the writer was not able to correlate it with any of the coals seen in Dickenson County. On Plummer Branch, which is 2 miles above the mouth of Birchfield Fork, the Upper Banner coal is between 5 and 6 feet thick.

At the head of Lick Creek, 4 miles southwest of Clintwood, the Cranes Nest Coal and Coke Company opened a coal bed which probably lies on top of the Gladeville sandstone and which has a considerable thickness. At this opening (No. 32) the bed measures 10 feet 5 inches and contains only 5 inches of shale. The same bed has been opened in two places on the head of Keel Branch, about 1 mile from Clintwood; in one place it is 6 feet 5 inches thick and in the other 10 feet 4 inches. There is very little waste in this bed, considering its thickness. The same bed has been opened on Georges Creek and near Clintwood, to supply the local demand for fuel, but is not quite so thick at the village coal banks as it is on Keel Branch.

Several small beds of coal have been opened along the banks of Cranes Nest River and on its smaller tributaries between Clintwood and the mouth on Pound River. The Upper Banner coal has been recognized at an elevation of 100 to 200 feet above the creek. It is 3 feet 4 inches thick where opened on Holly Creek (No. 34), 1 mile above the mouth, and nearly 4 feet thick on Levi Bartley Branch (No. 35). The Hawkins opening (No. 36), on the right of Cranes Nest River, below Nickels Gap, shows the Upper Banner 4 feet 1 inch thick, with only one thin parting, and at C. G. Rake's (No. 37), about a mile farther downstream, the same coal is 4 feet 3 inches thick, with

a 6-inch clay parting about 2 feet above the floor and two or three other very thin shale partings. In this same vicinity on Cranes Nest River, just opposite Delaney's mill (No. 38) and also opposite Delaney's house, the Upper Banner coal is over 4 feet thick. It has four partings, the thickest of which measures three-fourths of an inch. These openings, together with those in the vicinity of Mill Creek, on McClure Creek, lead to the assumption that the Upper Banner coal is fairly profitable for mining in this part of Big Ridge, which separates the two streams. The bed is several hundred feet below the top of the ridge and lies in a body several miles long, averaging over 1 mile wide.

POUND RIVER.

No coal openings were found on North Fork of Pound River. At the head of South Fork Reuben Boling has a bank (No. 39) at the water's edge which shows a bed 4 feet 3 inches thick, including a 10-inch seam of clay. At the mouth of Fox Gap Hollow there is a 28-inch coal, and near Bond Mill a 2-foot coal is reported. Farther down South Fork, at Thurston Banner's (No. 40), there are two openings which show 23 and 27 inches of coal, and at the mouth of Glady Fork (No. 41) there is a 3-foot bed without partings. At the mouth of South Fork (No. 42) openings made by Milburn Guillam show a bed which has a total thickness of 4 feet 4 inches. This, however, includes a 12-inch clay seam and 3 inches of bone.

On Indian Creek there is an old mine belonging to the Tidewater Company, in which 3 feet 4 inches of coal is visible, but water covers the bottom of the pit. Farther downstream, at J. H. Blair's (No. 43), a bed has been opened which is reported to be 5 feet thick, including one 8-inch parting. This is about 2 miles above the mouth of the creek. At the mouth a 16-inch coal is exposed near the road.

At the head of Dotson Fork of Bowlecamp Creek an opening on the George L. Baker place shows a bed of coal 8 feet 3 inches thick. The upper 5 feet of this bed is clean solid coal. Near the forks of McFalls Fork (No. 44), a coal reported to be 6 feet 6 inches thick is exposed in the bed of the creek, and on Hamilton Fork a pit back of Grant Mead's house (No. 45) has been opened on a coal bed which measures 4 feet 8 inches and contains one clay parting 6 inches thick.

A little over half a mile above the mouth of Georges Creek an opening (No. 46) at water level on the right-hand fork, made by John Trivitt, reveals a 4-foot coal containing 8 inches of clay in two partings. About a mile above the mouth, on the main creek, at J. C. Willis's (No. 47), this same coal is reported to be 2 feet 7 inches thick.

Near the head of Georges Creek, the coal which lies above the Gladeville sandstone and which has a considerable thickness on the head of Keel Branch and Lick Creek, tributaries of Cranes Nest River, has been prospected at several points and found to have considerable thickness.

At Samuel Elkins's (No. 48) this coal bed measures 5 feet 10 inches, and at Baumgardner's (No. 49), a little farther up the creek, 9 feet 8 inches. At the latter point it contains 16 inches of waste. The thickest section of this bed known to the writer is the Manuel Mullens opening (No. 50), three-fourths of a mile below Baumgardner's, where the thickness is 11 feet 3 inches, including an aggregate of 13 inches of waste in five partings.

Very few exposures of coal were seen on Pound River below the mouth of Georges Creek. There is a 16-inch bed of coal at the spring 30 feet below Nickels Gap (No. 51), and a 15-inch bed in the bank of Pound River directly below Nickels Gap.

In a hollow on the left of Pound River, 2 miles above the mouth of Cranes Nest River, at J. Sypherd's, a small pit reveals a coal bed probably just below the Gladeville sandstone, which has a thickness of 5 feet 2 inches and contains 11 inches of clay in two partings.

Coal was seen in two or three places on the right of Pound River on the flank of Pine Mountain, but in no case is the outcrop of commercial importance, the thickest being a 20-inch coal found about 50 feet below the top of the Lee conglomerate, on one of the forks of Skeet Rock Branch.

QUALITY OF THE COALS.

The following 16 analyses of coal from the Russell Fork basin in Virginia are from private reports, and show the chemical character of the principal coal beds in this field. The average of these analyses is 29 per cent volatile matter, 62 per cent fixed carbon, less than 1 per cent moisture, about 6 per cent ash, and 0.015 per cent phosphorus. The quality of the coals in this field is equivalent to that of the Pittsburg coking coal.

Analyses of bituminous coals from Dickenson County, Va.

	Opening.	Location.	Name of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.	Thickness.
										Ft. in.
1	Baumgardner (No. 49).	Georges Creek..	Clintwood..	2.44	33.26	58.682	4.90	0.718	0.007	9
2	Beverley (No. 53)..	Honeycamp Branch.	....do.....	.62	33.63	60.951	3.95	.849	.01	6 9
3				.....	33.96	62.02	4.02	.77	.....	6 9
4	John Lane (No. 54)	Clintwood.....	....do.....	.59	33.60	62.239	2.86	.711	.008	4 6
5	C. C. Kilgore.....	.....do.....	....do.....	.55	32.11	60.721	6.01	.609	.005	4
6	Keel (No. 33).....	.....do.....	....do.....	.70	33.60	60.90	4.80	.....	.....	.....
7	Keel, upper bench .	.....do.....	....do.....	.63	32.44	61.662	4.53	.738	.016	6 6
8	Keel, lower bench..	.....do.....	....do.....	.46	33.12	60.752	4.78	.888	.023	2
9	Viers.....	McClure Creek..	Upper Banner.	.438	29.862	63.355	5.44	.905	.005	5 9
10	Harden Branch (No. 11).	Fryingpan Creek.	....do.....	1.56	28.62	61.35	8.47	.....	.....	.....
11	Cany Fork.....	Indian Creek...	Tiller.....	.90	27.33	67.74	4.03	.....	.....	10
12	Barnett, upper bench.	Duty.....	....do.....	.304	25.436	64.594	8.88	.786	.021	4
13	Barnett, lower bench.	.....do.....	....do.....	.404	26.306	69.522	3.29	.478	.023	5
14	Taylor Sutherland (No. 10).	Bucu.....	Widow Kennedy?	.95	23.36	61.43	14.26	.....	.....	5 6
15	Taylor Sutherland	.....do.....	....do.....	.428	23.022	63.735	12.15	.665	.013	6
16	Sutherland.....	.....do.....	....do.....	.378	22.292	61.601	15.21	.519	.033	3

Analysts: 1, 2, 4, 5, 7-9, 12, 13, 15, 16, A. S. McCreath; 3, 6, Wuth & Stafford; 10, 11, 14, C. C. Tutwiler
Authority: 1-9, 12, 13, 15, 16, James T. Gardner; 10, 11, 14, Jansen Haines.

COKE.

The coals of this field duplicate in physical properties and chemical composition the coking coals on Toms Creek, and it is believed that for the most part they will be found to be good coking coals.

Car samples of the Clintwood coal taken from the Beverley opening (No. 53) on Honeycamp Branch and shipped to Chattanooga and Connellsville made coke of the following character, according to a private report of F. A. Stratton:

Analyses of Dickenson County coke.

	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.	Analyst.
72-hour	0.45	90.153	8.575	0.775	0.047	Wuth & Stafford.
48-hour	.031	91.224	7.695	.736	.035	Do.
72-hour	.....	90.91	8.34	.75	.....	Schoenberger Steel Co.
48-hour	.....	92.03	7.22	.75	.....	Do.
Do	1.50	92.30	6.30	.69	.032	Do.
Do	1.03	92.76	4.373	.841	.026	P. D. Langdon.

SUMMARY.

The evidence in the foregoing descriptions shows conclusively that the area between Sandy Ridge and Pound River is a valuable field of bituminous coal, in all parts of which there is at least one coal bed of minable dimensions. Doubtless further prospecting will reveal two or more coal beds of workable thickness above drainage level in many parts of the field. It is shown in the above notes that a coal bed having an average thickness of 8 feet is commercially minable around the head of Russell Fork; that the Upper Banner coal, averaging 4 feet in thickness, is present throughout a great part of the region; and that a bed approximating 7 feet in thickness underlies a small area near Clintwood. There is no known coal of value between Pound River and the crest of Pine Mountain. The chemical analyses show that these are high-grade bituminous coals and have only small percentages of impurities. There is evidence that some if not all of these coals will coke.

COAL MINING AT DANTE, VA.

By Ralph W. Stone.

INTRODUCTION.

Early in October, 1906, while making a reconnaissance survey of Dickenson County, Va., the writer was detained for a few days at Flint Gap on Sandy Ridge, 2 miles from the coal mines at Dante. The notes on which this paper is based were made at that time.

Dante, formerly known as Turkey Foot, is at the forks of Lick Creek, in the west corner of Russell County, Va., at the foot of the eastern slope of Sandy Ridge below Trammel Gap. It is near the north edge of the Bristol quadrangle, about 8 miles from Fink and St. Paul on the Norfolk and Western Railway, and is connected with Fink by a branch line known as the Lick Creek and Lake Erie Railroad, which is a part of the South and Western Railway. This gives an outlet for the coal to markets north, east, and south. Dante is 10 miles east of Toms Creek, where there are large coal mines and banks of coke ovens. A number of small mines are operating between these places.

Dante is in a mountainous country, its elevation above sea level being 1,770 feet, and the top of Sandy Ridge, 2 or 3 miles distant, averaging 3,000 feet. The hill slopes are steep and the ridges and valleys are narrow.

GEOLOGY.

STRATIGRAPHY.

The east edge of the coal field of Virginia is marked by a great fault which extends for many miles in a northeast-southwest direction across this part of the State. This fault brings Silurian limestone up above Carboniferous rocks. At Fink the limestone is seen abutting the overturned edge of the Lee conglomerate, which lies stratigraphically next below the coal-bearing formation. Dante is 7 miles west of this fault.

According to M. R. Campbell,[a] the Lee conglomerate lies nearly flat beyond the zone of disturbance at the fault, perhaps dipping slightly westward, and should be barely 300 feet below the sur-

[a] Geologic Atlas U. S., Bristol folio (No. 59), U. S. Geol. Survey, 1899.

face at Dante. A diamond-drill hole near the Dante schoolhouse encountered massive sandstone 257 feet below the surface, and conglomerate carrying small quartz pebbles at a depth of 299 feet. These appeared to the writer to be the same as the rocks seen at the top of the Lee formation in Pine Mountain, and to sustain Campbell's interpretation of the structure.

Above the Lee, and forming all of the surface in the vicinity of Dante, is the coal-bearing series of rocks known as the Norton formation. According to Campbell, this formation at Big Stone Gap is 1,280 feet thick and is overlain by the Gladeville sandstone, a coarse-grained, massive bed 100 feet thick. This sandstone is found near the top of Sandy Ridge, the highest points of which are occupied by the Wise formation, another series of sandstones and shales carrying a few beds of coal.

If the writer's interpretation of the top of the Lee in the above-mentioned drill hole is correct, there is a 60-foot bed of massive gray sandstone near the base of the Norton formation, or 190 feet below creek level. Two coal beds in the lower part of the formation were found in the midst of thin-bedded sandstone and shales within 150 feet of the surface.

A coal bed about 18 inches thick outcrops just above the creek at Dante, and the Widow Kennedy coal is 196 feet above water at the forks. The position of this coal is about 400 feet above the conglomerate and 125 feet above the 18-inch coal. It is succeeded by 240 feet of sandstones and shales, above which lies the Lower Banner coal, and 100 feet higher the Upper Banner coal. Just below Trammel Gap, or 250 feet above the Upper Banner, the bloom of a small coal occurs in the road at the base of a sandstone carrying white quartz pebbles. This may be the Gladeville sandstone. If so, the thickness of the Norton formation at this place is about 1,060 feet. From the gap to the top of Sandy Ridge the section is made up of sandstones and shales, with possibly two or three thin coal beds. Blocks of massive gray sandstone were seen at the top of the ridge and if these represent the Gladeville the thickness of the Norton formation is close to 1,300 feet.

STRUCTURE.

The rocks in this field have a fairly regular dip to the northwest at a low angle. This rather hinders natural drainage of the mines until they have been cut through to the far side of the hill.

COAL RESOURCES.

Introduction.—All mining at Dante is being done by the Clinchfield Coal Corporation, of Johnson City, Tenn. At this company's plant, which is known as the Clinchfield colliery, three beds are being worked by four mines, as follows: Widow Kennedy coal, mines Nos. 1 and 4;

Lower Banner coal, mine No. 2; Upper Banner coal, mine No. 3. The Widow Kennedy mines are at the foot of the Trammel Gap road on opposite sides of the creek, half a mile above Dante. Farther up on the left is the Lower Banner mine, and the Upper Banner is worked from several entries at the head of the creek. A brief description of these coal beds as found in each of the mines is given below.

Widow Kennedy coal, mine No. 1.—The Widow Kennedy coal outcrops nearly 200 feet above the creek at Dante, but the steep grade

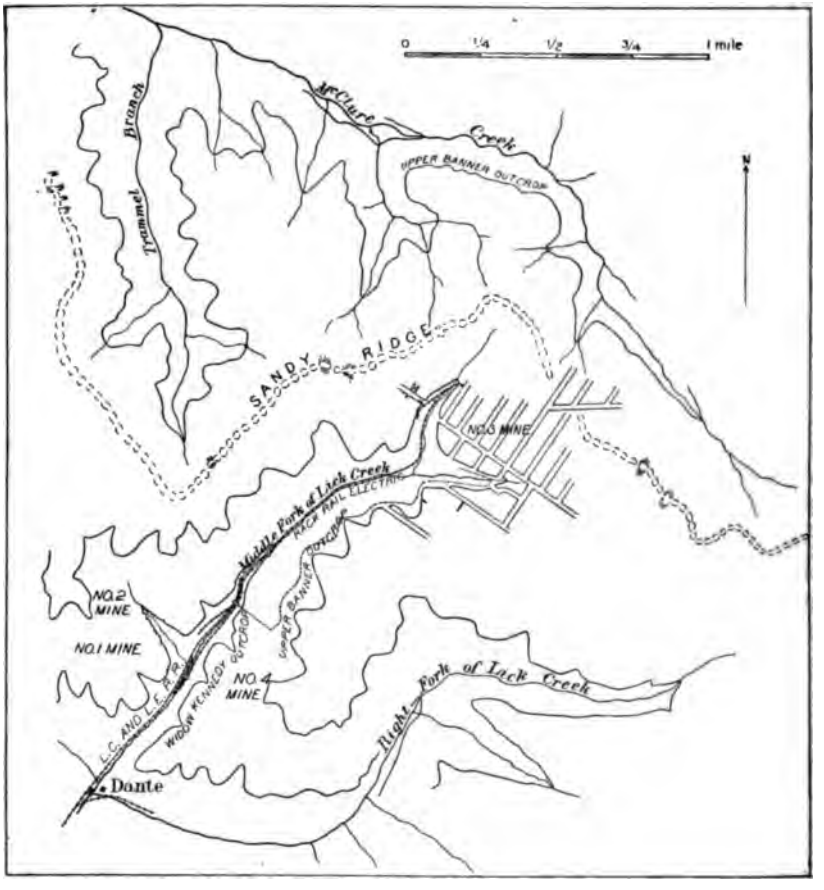


FIG. 1.—Map showing location of coal mines at Dante, Va.

of the stream and the opposing dip of the coal bring it somewhat nearer creek level at the point where it is mined. This is a curious bed, showing abrupt variations in thickness and character. In mine No. 1, which covers 15 or 20 acres on the left of the creek, the bed averages 7 feet in thickness, but in one heading it pinches out entirely and at other points it is from 12 to 14 feet thick. In parts of the mine it shows from 4 to 6 feet of clean coal without apparent bedding or

cleavage. This condition, however, is not persistent, for a peculiarity of the Widow Kennedy coal is that in many places it is crushed, and slickensided as if it had been subjected to squeezing and lateral movement. Slick faces dipping in all directions are encountered and streaks and balls of clay are included in the coal bed. The coal under these conditions is laminated or flaky, and the thin layers of clay in it show the movement by their curved and contorted outline. One heading in this mine passes through 20 feet of alternate thin layers of coal and clay standing vertical. Much of the badly shattered coal is so dirty as to be unmarketable, but in some places the clay balls are so easily separated that the coal can be cleaned by hand.

The floor in mine No. 1 is sandstone, and the roof is also, but is separated from the coal in places by a foot or less of draw slate. The roof holds well. Here and there thin lenses of sandstone separate 1 inch or 2 inches of flat coal next the roof from the top of the main bed.

Widow Kennedy coal, mine No. 4.—In mine No. 4 on the opposite side of the creek the average thickness of the Widow Kennedy coal is from 3 to 3½ feet. The coal is not badly crushed, but the top 2 inches is dirty and lies in thin flat plates or layers. Throughout the mine the floor is sandstone, which is fairly regular with only minor unevennesses like ripple marks. Draw slate usually separates the coal from the sandstone in the roof. This draw slate, however, is of variable thickness, ranging from a few inches up to 4 feet. In room No. 2 off the main heading, within a distance of 65 feet, the draw slate pinches down from 2 feet until the sandstone rests upon the coal. A thin layer of plastic clay lies between the coal and the roof.

The main heading in mine No. 4 shows 6 feet of coal with two diagonal clay streaks and 1 foot of draw slate. About 300 feet farther in the draw slate thickens to nearly 4 feet and the coal thins to 2 feet, the upper half of which is soft, dirty, laminated coal, or "rash." In room No. 2 from the main heading there is from 6 to 7 feet of solid coal with almost no clay balls, but the top 2 inches in spots is laminated. The face of No. 6 right crosscut shows 50 inches of coal with two diagonal or inclined clay streaks 1 inch thick. In one place the upper 10 inches of the coal is contorted and so mashed that it breaks to slack when mined. In the face of No. 5 crosscut the bed has a hard draw-slate roof and a sandstone floor; it is 4 feet thick but contains 6 inches of clay about a foot above the floor. In crosscut No. 4 the face of room 1 shows 4 feet to 4 feet 2 inches of coal with 2 inches of clay between coal and draw slate. The coal here is free from dirt and fairly hard, but it contains some soft crushed streaks and diagonal cleavage. In room No. 2 of the same crosscut there is 5 feet of solid coal with 2 inches of clay on top. Room No. 3 has 3 feet 4 inches of coal, with one-half inch of clay between it and the draw slate, which is 6 inches thick. Much of this coal shows hard slick faces that

appear to have been produced by movement in the bed. The writer took a sample of the entire bed in No. 2 crossheading, where there is 3 feet 9 inches of solid coal. The analysis is given with others on page 74.

Lower Banner coal, mine No. 2.—The Lower Banner bed is worked at what is known as mine No. 2, on the left of the creek, 200 yards north of mine No. 1. The thickness of the bed averages from 3 to 3½ feet in the main heading, but increases toward the outcrop on the far side of the hill. This heading has been driven through for drainage. In the furnace heading the coal measures 6 feet 2 inches, but thins to 5 feet 10 inches farther under the hill. A sample, the analysis of which is given on page 74, was taken in room No. 4 off the left entry, where the section is as follows:

Section of Lower Banner coal in mine No. 2, Dante, Va.

	Inches.
Coal, alternate bright and dull bands	19
Coal, laminated	3
Coal, solid	17
Fire clay	6
Coal, bright	2
	47

The fire clay and bottom coal were not included in this sample.

In the face of the third left heading and of a cross entry the following sections were measured between the shale roof and the clay floor:

Sections of Lower Banner coal in mine No. 2, Dante, Va.

		Third left heading.	Cross entry.
		Inches.	*Inches.*
Coal	Mined	24	4
Bone or rash	Mined	1	2
Coal	Mined	18	20
Coal, sticks to clay	Left in floor	1	1
Fire clay	Left in floor	1	2
Coal	Left in floor	2	3
Fire clay	Left in floor	6	.....
Coal	Left in floor	2	.....
		55	32

The bed is mined down to the 1 inch of coal which is left on top of the fire clay. In one heading the bed thins down to 18 inches of coal, with a thin laminated streak 4 inches from the top, then to a minimum of 16 inches of solid coal. Beyond this point the solid coal increases to 17 inches, with 10 inches of laminated coal on top, and farther on 1½ inches of good coal appear above the laminated.

Upper Banner coal, mine No. 3.—The Upper Banner coal has been mined more extensively than either of the others. The entries, of

which there are nine, are at the head of the creek under Trammel Gap and around to the right of the head. Mine No. 3 is working on a 1,160-acre tract. The main tunnel, when completed, will be about 3,200 feet long and No. 2 crosscut about 2,400 feet. The coal averages 5 feet in thickness, with more at 5 feet 6 inches or 5 feet 10 inches than at 4 feet. Draw slate from 6 to 10 inches thick lies on top of the coal and becomes plastic when wet. This is usually overlain by 1 inch to 6 inches of coal, which hangs to the sandstone roof. In some places the sandstone cuts out the draw slate, and where this happens the coal bed is thin. The slate floor is from 4 to 19 inches thick, over sandstone.

The following sections were measured at different points in the mine:

Sections of Upper Banner coal in mine No. 3, Dante, Va.

[Inches.]

Coal	21	22	23
Sandstone	1	1	1½
Coal	10	10	10
Shale, gritty	½	½	1
Coal	30	33	36
	62½	66½	71½

At No. 9 opening a 10-inch coal bed lies 7 feet below the Upper Banner. The intervening rocks are sandstone and shale.

In a part of mine No. 3 known as Hylton No. 1 a sandstone lens cuts the coal down to 16 inches. This sandstone, however, does not show in Hylton No. 2, about 60 feet away. In the left butt entries off the main tunnel the floor dips about 10 feet in 60 feet, then rises again, making a sag in which water collects. In one entry the water touches the roof.

A sample of the Upper Banner was taken at butt entry No. 6, off the main gangway, where the section of the bed is as follows:

Section of Upper Banner coal in mine No. 3, Dante, Va.

	Inches.
Sandstone roof.	
Draw slate	8
Coal	22
Sandstone	1
Coal	10
Shale, gritty	½
Coal	24
Parting.	
Coal	5
Shale floor.	
	70½

The 24-inch bench contains 4 inches of dull, hard splint coal.

ANALYSES.

Samples of these three coals were taken by the writer. Each sample was crushed and quartered in the mine and sealed in an air-tight can. They were analyzed at the fuel-testing plant of the United States Geological Survey at St. Louis as received, without loss of moisture. These analyses have been recalculated on an air-dried basis to give analyses representing the condition of the coals as delivered to the consumer and to make them more readily comparable with analyses of other coals made from air-dried samples.

Analyses of coals mined at Dante, Va.

[F. M. Stanton, analyst.]

	Widow Kennedy.	Lower Banner.	Upper Banner.
Laboratory No.	3947.	4057.	3942.
Loss of moisture on air drying	0.80	1.80	1.30
Moisture	1.90	2.79	2.36
Volatile matter	31.54	32.11	32.40
Fixed carbon	60.87	59.30	57.92
Ash	5.69	5.80	7.32
Sulphur	1.47	.84	.66
Recalculated on air-dried basis:			
Moisture	1.11	1.01	1.07
Volatile matter	31.79	32.70	32.83
Fixed carbon	61.36	60.39	58.68
Ash	5.74	5.90	7.42
Sulphur	1.48	.85	.67

Analyses of the Widow Kennedy and Lower Banner coals at the Dante mines, furnished by the Clinchfield Coal Corporation, are as follows:

Analyses of coals mined at Dante, Va.

	Widow Kennedy.		Lower Banner.
Moisture	0.90	0.85	0.95
Volatile matter	38.46	35.25	37.61
Fixed carbon	56.26	58.14	55.62
Ash	4.38	5.76	5.82
Sulphur	1.12	1.13	.82

These results show that they are all high-grade bituminous coals. The sample of the Widow Kennedy coal taken by the writer represents that bed in its best condition, and the low percentage of ash in the other analyses of the Widow Kennedy coal suggests that the samples were taken at particularly favorable points. A sample including the crushed or laminated coal, called "rash" at Dante, which is so common in this bed, probably would show a much higher percentage of ash. The sulphur content is so low as to be unobjectionable.

It is presumed that these coals would make a high-grade coke, for the coal mined from the same beds at Toms Creek is coked successfully on a large scale. The Dante and Toms Creek coals are identical in physical structure and chemical character.

METHOD OF MINING.

The room and pillar method of mining is used at Dante—in the old workings rooms 24 feet wide with 50-foot centers, and more recently 30-foot rooms with 60-foot centers. Practically all the mining is pick work, and the coal is shot from the solid. Two Goodman electric undercutting machines have been used in mine No. 3 since September, 1906.

At mines Nos. 1, 2, and 4 all haulage is done by mules. Cars are lowered from the mines by a gravity incline to tipples on the railroad. At mine No. 3 cars are gathered and hauled out by mules in all entries west of No. 5. At entry No. 5 and those farther east this work is done by motors. Five 4-ton gathering motors are in use, besides which there are one 20-ton, one 15-ton, and one 8-ton motor. These are all the Goodman type of motor, except the 8-ton, which is a Jeffrey. The trips of mine cars are hauled by a small steam locomotive about a mile along the mountain side to a gravity incline which connects with a tipple 300 feet below.

A rack rail electric-motor system is being installed between the main gangway of mine No. 3 and a new tipple which is to serve mines Nos. 3 and 4. When the new tipple is completed the Upper Banner coal will be shipped as mine-run, and the Widow Kennedy from mine No. 4 will be screened for slack and lump. The coal from mines Nos. 1 and 2 is screened now, but is only a small part of the output because there are only 10 or 12 miners working in the two mines.

Ventilation is by furnace in mines Nos. 1, 2, and 4, and in entries 1, 2, and 3 of mine No. 3. The remainder of mine No. 3 is ventilated by a 12-foot suction fan.

Natural drainage is obtained in mines Nos. 1 and 2, which are driven down the dip to the outcrop on the far side of the ridge. Mine No. 4 is skillfully managed and drains out the main entry. No. 3 can not have natural drainage until it is driven through to Trammel Creek. Then, on account of rolls or sags, it may be necessary to do some ditching. At present the water is hand pumped, siphoned, and bailed onto cars. Two electric centrifugal pumps will soon be installed at this mine.

MARKET.

Most of the output of the mines at Dante goes to the Atlantic Coast Line and the Southern Railway for railroad use. Some of the Widow Kennedy coal is used for domestic purposes. The Clinchfield colliery produces about 15,000 tons of coal a month, and the output is being slowly increased.

THE NORTHERN PART OF THE CAHABA COAL FIELD, ALABAMA.

By Charles Butts.

INTRODUCTION.

The Cahaba coal field, named from Cahaba River, has been studied for many years by Joseph Squire, whose excellent report, with detailed map, was published by the Geological Survey of Alabama in 1890. This report has been a valuable guide to the field, and, although the present results differ in some particulars from those published by Mr. Squire, the writer testifies to the general worth of his report and acknowledges indebtedness to it for much information. Much help has been derived from other sources also. Mr. W. B. Allen, of the Tennessee Coal, Iron and Railroad Company, kindly furnished maps of parts of the field, showing coal outcrops and locations of prospect pits, which were of great assistance, and many others contributed information. All such help is gratefully acknowledged.

The survey on which the present report is based was made in 1906 by Mr. Chester W. Washburne, Dr. William F. Prouty, assistant State geologist of Alabama, and the writer. To the loyal and efficient assistance of Messrs. Washburne and Prouty is due much of whatever value this report may possess. Mr. T. E. Williard also rendered valuable aid by his collection of fossil plants.

The geology of the Cahaba field is rather difficult, and, especially in the southern half of the area here included, there are obscure and still unsolved problems of stratigraphy and structure which it is hoped will be cleared up by further study. This report and the accompanying map are therefore provisional only and subject to change in a more complete and final report to be made at a later date.

LOCATION AND EXTENT.

The Cahaba coal field is relatively long and narrow and trends N. 45° E. The part under discussion lies in general along the boundary lines between Jefferson County on the northwest and Shelby and St. Clair counties on the southeast. (See Pl. V, p. 80.) Its length is about 40 miles, its greatest width nearly 6 miles, and its least width a little more than 3 miles. Its total area is 150 square miles.

TOPOGRAPHY.

SURFACE RELIEF.

The altitude of the area mapped ranges from 360 feet above the sea on Cahaba River at its southern margin to 1,100 feet on the crest of Shades Mountain near Oxmoor. The most salient features of the

surface are the long parallel ridges following the general direction of the field. At intervals the continuity of these ridges is broken by transverse valleys that have been eroded by streams finding an outlet in Cahaba River, which flows along the middle of the field. As is shown in the section on structure (pp. 80–82), this conspicuous linear and parallel arrangement of the ridges and valleys is an expression of the character and attitude of the rocks underlying the surface.

DRAINAGE.

Cahaba River, the main stream, follows the middle of the field for nearly its whole length and receives the waters from both sides through the generally small lateral streams. Shades Creek is a good-sized stream flowing parallel to the west side of the area, from which it receives a few small tributaries.

ACCESSIBILITY.

The transverse streams, as well as the Cahaba itself, have cut deep gaps through the ridges at many points, and at other points there are low wind gaps through which shallow cutting only is needed for railroad construction. The valley of Stinking Creek through Blackjack Ridge, followed by the Seaboard Air Line Railway, and that of Abes Creek through Blackjack, Grassy, and Chestnut ridges, followed by the Southern and the Central of Georgia railways, are examples of the stream-cut gaps. The low place in Shades Mountain, known as Brock Gap, followed by the Louisville and Nashville Railroad, and that through the same ridge 2 miles farther south, known as Genery Gap, crossed by the Southern Railway, are wind gaps. The longitudinal valleys separating the ridges offer easy access to the mines by spurs from the main lines of railroads which cross the field. The spur of the Central of Georgia Railway that leaves the main line at Henryellen and runs northward along the outcrop, first of the Mammoth bed and then of the Harkness bed, to the Margaret mine, which is beyond the limits of the area mapped, is an example of the possibilities of railroad building to points favorable for opening the various coal beds.

GEOLOGY.

STRATIGRAPHY.

The rocks of this coal field are shale and sandstone, interstratified with beds of coal. They are of Pottsville age and constitute the lower subdivision of the rocks known as the Pennsylvanian series.

In the Birmingham district there is doubt as to what shall be regarded as the lower limit of the Pennsylvanian series. Mr. Squire, in the cross sections accompanying his report on the Cahaba field, has placed the bottom of the "Coal Measures" 200 to 400 feet below the Brock coal bed, and that limit appears to have the sanction of the Alabama Geological Survey. It has been the custom of the geologists of the United States Geological Survey, however, to extend

the lower limit of the Pennsylvanian series downward to the top of the Bangor limestone, but, for the reasons stated below, that custom is not warranted in this region. Along the west side of the Cahaba field there are, between the Brock coal bed and the Bangor limestone or equivalent horizon, 1,200 to 2,200 feet of gray shale and sandstone which are apparently identical in character with the coal-bearing rocks. A very few fossils have been collected from these rocks, however, that have Mississippian affinities and indicate the "Lower Carboniferous" age of the beds. These rocks are a lithologic unit and, in the writer's judgment, should not be divided. They are therefore regarded as Mississippian, and the upper limit of this series is fixed at the bottom of the Brock coal bed. This interpretation involves the recognition of a great unconformity between the Pennsylvanian and the Mississippian series in this region.

The sandstone strata of the coal-bearing rocks do not commonly exceed 100 feet in thickness, and they are generally made up of layers from 6 inches to 2 feet thick.

If we take the bottom of the Brock bed as its lower limit, the total average thickness of the Pennsylvanian series is more than 6,000 feet. The following is a generalized section:

Generalized section of the coal-bearing rocks of the Cahaba coal field.

		Minimum.	Maximum.	Average.[a]
		Feet.	*Feet.*	*Feet.*
Shale and sandstone with coal beds at intervals from top of section		.....	1,300	1,300
Coal, Mammoth-Helena bed		.....	.....	10
Shale and sandstone		100	140	118
Conglomerate		10	80	45
Coal, Thompson or Conglomerate bed		.....	.....	4
Shale and sandstone with thin coal beds		200	270	223
Coal, Little Pittsburg bed		.....	.....	2
Shale and sandstone, Moyle coal bed at top and other thin coals in some sections		130	380	292
Coal, Black Shale bed		.....	.....	2
Shale and sandstone		100	150	125
Coal, Buck bed		.....	.....	2
Shale and sandstone with coal beds, including Squire's Coke, Atkins, and Schute beds, etc., in the Henryellen basin		125	775	500
Shale and sandstone		375	950	660
Coal, Wadsworth bed		1	3	2
Shale and sandstone		250	750	410
Coal, Harkness bed		1	8	4
Shale and sandstone with thin coals; sandstone of Owen Mountain at base		325	600	440
Shale and sandstone with Nunnally group of coals, two to six beds		50	400	250
Shale and sandstone; includes sandstone of Chestnut Ridge at base	"Millstone grit," probable equivalent of Lookout formation.	425	1,000	618
Shale and sandstone with Gould group of coals		50	275	180
Shale and sandstone; includes two white, siliceous, in places conglomeratic, sandstones, making two ridges, one known in different parts as Grassy Ridge, Flat Ridge, or Pine Mountain, and the other as Blackjack Ridge or Shades Mountain; one to three thin coals between the sandstones		800	1,200	918
Coal, Brock bed		½	1½	1
		.....	.....	6,105

[a] The averages in the last column are not derived alone from the maximum and minimum measurements here given, but from those and a number of others from the individual vertical sections on Pl. VI.

The preceding section differs from that of Squire[a] in its greater detail. It has been compiled from the vertical sections on Pl. VI, which are themselves derived from horizontal sections across the field at intervals from Black Creek on the north to the Louisville and Nashville Railroad on the south. (See Pl. V.)

A great variation in the thickness of the subdivisions in the generalized section is shown by the maximum and minimum measurements. These irregularities become still more apparent on the study of the individual vertical sections (Pl. VI). Two explanations can be given. The first is that great irregularities probably exist in the rocks themselves, and the second that the variations are in part due to errors of measurement.

According to David White, who has studied the fossil plants collected in the Cahaba field, the Helena bed, near the top of the section in the area under discussion, does not lie at a higher horizon than the middle of the Sewell formation of West Virginia. The interval from this horizon to the bottom of the Pottsville in West Virginia is approximately 1,500 feet. During lower and middle Pottsville time, therefore, about three times as great a thickness of sediment was deposited in the Cahaba field as in the Pottsville of West Virginia, or, in other words, the rate of deposition was three times as great in the former as in the latter field. Great inequalities in the thickness of sediments within comparatively short distances probably resulted from such rapid deposition.

Errors of measurement are inevitable where, as in this field, thicknesses have to be determined from the dip of the rocks and horizontal distance between the outcrops of observed beds. The number of observations is often insufficient because of lack of exposures, and many dip measurements are inaccurate on account of the deceptive appearance of the beds, so that when the exposure is small, it is nearly impossible to determine the true dip. As is well known, dips vary constantly from place to place, and unless there are many observations the average dip as determined may be several degrees in error.

The sections also show great variations in the number of coal beds in some of the groups, more particularly in the Nunnally and Gould groups. Thus in the section along the road from Birmingham to Leeds no less than six thin beds of coal are shown in the Nunnally group; in the Louisville and Nashville Railroad sections there are but two beds to be seen in this group, with possibly a third lower down but not exposed; and in the section along the road eastward from Trussville there are three thin coals showing close together. These variations are doubtless due partly to actual differences in the number of beds in the different sections and partly to the fact that all the coals of a group are not exposed in most of the sections.

[a] Rept. on Cahaba coal field, 1890, p. 14.

STRUCTURE.

The Cahaba coal field is a structural trough or syncline which is unsymmetrical, being deepest near the southeast margin. The trough is bounded on the southeast by a fault, known as the boundary fault, along which much lower and older rocks of Cambrian age are in contact with the coal-bearing rocks. In the northwestern half of the field the rocks generally dip to the southeast at angles ranging from 10° to 15°; nearer the axis of the trough the dip reaches 25° to 45° SE., while on the southeast side of the axis the dip is reversed and the rocks are abruptly bent upward to a vertical or nearly vertical attitude, as shown by the cross sections on Pl. V.

As noted above, the general structure of the field is comparatively simple, but there are a number of minor features which tend to complicate it. These consist of strike faults and of subordinate folds either following the strike or running transversely or obliquely across the main trough and creating thus a number of small independent basins. These basins are described below, and in following this description the reader should constantly refer to the map (Pl. V).

Simple but unsymmetrical structure prevails in this field north of Henryellen. About 1 mile south of that place a subordinate fault diverges from the boundary fault and follows a more westward course to Hogpen Branch, in the northeast corner of sec. 26, T. 17 S., R. 1 W., where it in turn seems to divide into eastern and western faults. The eastern one of these last-mentioned faults runs southward and rejoins the main fault near the point where the Birmingham-Leeds highway strikes the base of Pine Ridge. The western fault follows Hogpen Branch southwestward nearly to its mouth, whence it is supposed to continue along a southwesterly course and to connect with a fault encountered in an old mine west of the pumping station of the Birmingham waterworks.

As a result of the movement which produced the faults described above, the lenticular area of rocks, beginning 1 mile southwest of Henryellen and including, in order from north to south, all formations from the Knox dolomite to the lower part of the coal-bearing rocks, was thrust up as a block between the main boundary fault on the east and the faults on the west.

Squire mapped and described the Henryellen basin as a regular trough extending from the north end of the Cahaba field to the vicinity of the pumping station named above. It was found, however, that a subordinate basin, extending from Hogpen Branch to the pumping station, forms the south third of Squire's Henryellen basin. This is here named the Little Cahaba basin on account of its proximity to Little Cahaba River, which crosses its south end. This subordinate basin or trough is narrow and deep, with steeply dipping rocks on

each side. The north end of the Little Cahaba basin is closely folded into a number of narrow anticlines and synclines that are shown on the map (Pl. V) by the lines indicating the outcrop of a number of beds of sandstone which, standing nearly vertical, make prominent ridges. These outcrops were actually followed out in the field, and the main features of the structure were determined beyond a doubt.

Between the basin just described and the Acton basin next on the south is an area in which sufficient geologic work has not yet been done to permit mapping and description. It seems probable that the structure is synclinal in the northern part. The location, form, and extent of the Acton, Helena, and Eureka basins are shown on the map. The anticline separating the Acton and Helena basins is clearly the continuation of that shown along the Louisville and Nashville Railroad between the Cahaba River bridge and Tacoa station. The fold between the Helena and Eureka basins appears to be a low swell transverse to the general strike.

The anticline just mentioned is to all appearances a closed and upright fold. In the cut at Tacoa there is, on the limb of the main fold, a subordinate fold, which is also closed and upright. These features are exhibited in the Louisville and Nashville Railroad section, on Pl. V.

Along the natural continuation of the anticlinal belt, southwest of .he Louisville and Nashville Railroad, exposures are generally poor ınd not sufficiently connected to reveal the structure with certainty. The observed dips, however, are all southeastward, but vary greatly n amount. According to the writer's interpretation the folds, which ıre upright on the Louisville and Nashville section, have been over-urned to the northwest in the Bamford-Mossboro section, and per-aps additional folds or faults have been developed. The structure this river belt is confessedly obscure and not well made out. It is ·ped that further investigation will reveal other facts which will ·ow more light on the structure. It is plain that some such struc- as that indicated in the Bamford-Mossboro section exists at the h end of this belt, for without the repetition of beds as shown in the vertical distance from the conglomerate lying between the a and Thompson beds to the Gould bed would be 7,000 feet, s in all the other sections this distance is less than 4,000 feet. t just described is mapped by Squire and designated by him rior fault vertical measures." As shown above, however, re not vertical, except probably from the vicinity of the d Nashville Railroad northward, and no positive evidence ıce of a fault was discovered, although such a supposition asonable. At Sydenton the structure is synclinal, what he same bed of coal with opposite dips being mined on the syncline. The abandoned mine at Sydenton followed

the bed down the southeasterly dip, and an older abandoned mine just west of the railroad bridge over Cahaba River followed the dip to the northwest. According to report the bed has never been followed across the syncline between these mines, so it is not certain whether they are connected or separated by a fault along the syncline. The converging strike of the beds south of the railroad indicates that the syncline runs to a point like the end of a canoe about a mile southwest of Sydenton, in the southeast corner of sec. 8, T. 20 S., R. 3 W. The coal bed mined at Sydenton probably outcrops around the point of the syncline, but it is not possible to trace it, although associated sandstones have been followed almost around the point.

A broad, shallow syncline, the axis of which lies along the course of Little Valley Mountain, extends from New Hope to that part of Shades Mountain which follows a north-south course south of Oxmoor. Along the east side of this syncline are Jones and Dolly ridges, which are made by the sandstones of Flat Ridge and Shades Mountain, respectively. Dolly Ridge is an anticline, the sandstone rising from the syncline to the west at a low angle and then plunging abruptly downward to the east at a high angle. This anticline is continued to the southwest through Refuge and across Patton Creek, gradually flattening out and probably disappearing not far south of that creek. Just to the east of Dolly Ridge is another sharp, narrow ridge made by the sandstone of Flat and Jones ridges as it dips to the east at an angle of about 50°.

To the northeast of New Hope, in secs. 12 and 14, T. 18 S., R. 2 W., there is a noticeable flattening of the rocks, which shows in the section north of the pumping station (Pl. V, p. 80). This flattening is also shown by the expansion of the outcrop of the sandstone of Chestnut Ridge, in the above-described section. Another flattening, likewise shown by the expansion of the outcrop of the same sandstone, occurs between the pumping station and the Caldwell ford, including sec. 34, T. 18 S., R. 2 W. In the SE. ½ sec. 34 a low northwest dip is believed to exist.

GENERAL CORRELATION OF COALS.

Before proceeding with the description of individual coal beds it is necessary to discuss the general correlation and identification of the several beds in the different parts of the field. This discussion begins with the lower beds of the field, because there is no doubt concerning the tracing and identification of these beds from one end of the area to the other. The certainty with respect to these lower beds is due to the presence at the base of the measures of three quartzitic sandstones generally known as the "Millstone grit." These sandstones are hard and resistant, and on account of their attitude make conspicuous and continuous ridges. The uppermost sandstone of these three makes

Chestnut Ridge; the one next below makes the ridge which in the southern part of the area is known as Pine Mountain, in the middle part as Flat Ridge, and in the northern part as Grassy Ridge; the lowest makes the ridge known in the southern part as Shades Mountain and in the north as Blackjack Ridge. By the aid of these sandstones it is possible to identify their associated coals with certainty. Thus the Brock bed, the type locality of which is Brock Gap, lies less than 100 feet below the sandstone of Shades Mountain and Blackjack Ridge. The type locality of the Gould bed, or Gould group of beds, is the old Gould mine in the vicinity of the present Star Cahaba mine No. 1, about 1 mile west of Sydenton, in the NW. ¼ sec. 8, T. 20 S., R. 3 W. This group, therefore, lies between the sandstone of Pine Mountain and Grassy Ridge and that of Chestnut Ridge, and it can be identified everywhere with certainty. Attention may be called to the fact that Squire's map of the Cahaba field shows the outcrop of the Gould coal to the west of Grassy Ridge. Squire, however, applied the name Grassy Ridge to the north end of Chestnut Ridge instead of to the north end of Flat Ridge, so that there is no real disagreement in the identification of the coals.

The Nunnally group of coal beds, the type locality of which is the Nunnally place, on the Louisville and Nashville Railroad, about three-fourths of a mile northwest of Sydenton, lies next east of Chestnut Ridge and can be traced with scarcely a break from one end of the area to the other. In the northern part of the field this group can be identified from its outcrop along the west flank of the prominent ridge known as Owens Mountain.

Next above the Nunnally group lies the Harkness bed, the type locality of which is the old Harkness place, on the Louisville and Nashville Railroad, one-half mile northwest of Sydenton, in the southwest corner of sec. 4, T. 20 S., R. 3 W. The identification of this bed north of the type locality is less certain than that of the Gould and Nunnally coals, partly because it has no key rock that can be traced throughout the field and partly because it is involved in the fault along Hogpen Branch. The coal bed apparently can be identified with some degree of certainty as far north as Acton Creek. Its outcrop may continue northward, parallel to the Nunnally bed, to a point about 1 mile northeast of the pumping station, where it is probably cut out by the above-mentioned fault. In the northern part of the area a thick bed outcropping along the east side of Owens Mountain has been identified as the Harkness, and this identification appears to be correct. This bed has been traced southward to a point (No. 52 [a]) in the southeast corner of sec. 32, T. 17 S., R. 1 W. Two or three miles south of this point the outcrop probably runs into the fault. East of the fault between the pumping station and Hogpen Branch

[a] Numbers refer to corresponding numbers on Pl. V.

the outcrop of the Harkness bed is believed to be repeated by the upthrow of the fault, the identification of the bed depending on both stratigraphic and paleobotanic evidence. Plants collected from a bed outcropping on the Birmingham-Leeds road (No. 54), near the center of sec. 34, T. 17 S., R. 1 W., are regarded by David White as probably associated with the Harkness coal. The outcrop of this bed can be traced, as shown on the map, by openings at points Nos. 55 and 56, by a natural exposure in the road at point No. 57, in the northwest corner of sec. 18, T. 18 S., R. 1 W., and by the relation of the outcrop to continuously traceable sandstones that are also shown on the map.

The stratigraphic evidences for the identification here made are as follows: First, the bed regarded as Harkness is the first known bed above the Nunnally group which can be certainly identified in the section north of the pumping station (Pl. VI, p. 86); second, the supposed Harkness bed in this section is 1,800 feet below a coal bed which lies about 100 feet above a good conglomerate. The significance of this circumstance will appear from the following discussion. In the Black Creek section (see Pl. VI) the interval between the Mammoth and Harkness beds is 1,500 feet, in the Trussville section it is 1,600 feet, in the Central of Georgia Railway section 1,600 feet, and in the Southern Railway section 1,800 feet. On Snake Branch, 1½ miles south of the Southern Railway, the interval is 1,800 to 1,900 feet. There is no doubt as to the identity of the two beds in the last-named locality. Furthermore, about 150 feet beneath the Mammoth bed is a conglomerate which shows in the Trussville and Central of Georgia Railway sections and also appears from Snake Branch southward to Hogpen Branch, where both the Mammoth bed and the underlying conglomerate are cut out by the fault already described. The conglomerate increases in thickness toward the south and becomes more conspicuous near the fault. Now, in the Little Cahaba basin, about 4 miles southwest of the point on Hogpen Branch where the Mammoth coal and the conglomerate run into the fault, there is, as shown in the section north of the pumping station (Pl. VI), a conglomerate underlying a coal 1,800 feet below which, as stated above, lies the supposed Harkness bed. These circumstances point not only to the fact that the supposed Harkness bed in this section is really such, but also to the conclusion that the coal and conglomerate near the top of the section are the Mammoth coal and its conglomerate.

The Wadsworth bed, the next of any importance above the Harkness, presents no particular difficulties of correlation if the identification of the Harkness as stated above is correct, for a bed in corresponding position to the Wadsworth has been observed generally north of the Louisville and Nashville Railroad. The type locality of the Wadsworth is at Tacoa station, where it was mined years ago by Frank Wadsworth. South of Tacoa station the outcrop appears to

run in a nearly straight southwesterly course as mapped. To the north and west the outcrop is repeated as a result of the structure, so that the old mines on both sides of the river in the vicinity of Sydenton are, with almost no doubt, in this bed.

In the 1,000 to 1,500 feet between the Wadsworth bed and the conglomerate near the top of the measures there are many thin coal beds, and any correlation of individual beds throughout the length of the field would be at best very doubtful. Squire has mapped and shown in various sections ten to fifteen coal beds in this interval, including in ascending order the Schute, Atkins, Coke, Buck, Black Shale, Little Pittsburg, Thompson, and other thin beds. In only one section, that of the Acton basin at Bains Bridge (Pl. VI), did the writer see so many coal beds in this interval. In that section there are at least thirteen beds, many of them being indicated by thin streaks of smut. It is probable that a large number of these are thin and close together. As many or more beds may be present in this interval all along the field, but not exposed, for exposures are generally poor between the horizon of the Black Shale and Buck coal beds and the Wadsworth bed. It is entirely possible that thin coal beds in this interval are present in some sections and absent in others, and that some of these may locally reach a considerable thickness. Many of the correlation lines drawn on Pl. VI are meant to indicate that the coal beds connected lie at about the same horizon, but not that they are necessarily identical.

At this point the question of the correlation of the Mammoth with the Helena bed naturally comes up. The reasons for regarding the coal above the conglomerate in the Little Cahaba basin as the Mammoth bed are fully set forth on page 84. It is also clear and recognized by all workers in this field that the conglomerate and the coal above it are the same as the conglomerate and Helena coal in the Eureka, Helena, and Acton basins. It follows, therefore, that the Mammoth and Helena beds are the same. This conclusion is strengthened by the fact that, so far as the writer has discovered, there is no other conglomerate above the "Millstone grit" in this part of the Cahaba field. It is probable that the conglomerate was all deposited at the same time and formed a continuous bed ranging gradually from thick and coarse at the south to thin and fine at the north. It should be noted in this connection that the interval between the Harkness and Helena beds in the Acton basin and along the Louisville and Nashville Railroad (see sections 9 and 10, Pl. VI) is about 2,400 feet. This is an objection to the correlation of the Mammoth and Helena beds, but is not fatal to it, for, as has been noted, there is a gradual increase of this interval from north to south down to Hogpen Branch, and a further increase from the Little Cahaba basin to the Acton basin is in accord with the general thickening of the coal-bearing rocks toward the southwest.

Squire, in his report on the Cahaba field, regarded the Buck and Black Shale beds of the Louisville and Nashville Railroad section near Helena as the equivalents of the Mammoth bed. He expressed the belief that the two branches of the Mammoth which are separated by 10 feet of shale in the Southern Railway section become more and more widely separated to the south, until they are 100 feet apart, and form the Buck and Black Shale beds at Helena. In conversation with the writer, however, Mr. Squire said he had no positive evidence for such an opinion. Possibly he reported it as a matter of common belief. In the writer's judgment there is no stratigraphic evidence for such a conclusion.

DETAILED DESCRIPTION OF THE COAL BEDS.

In this description only those coal beds will be included that, so far as known, are in some part of the area under discussion 2 feet or more in thickness. In descending order the beds are, according to the writer's identification, the Mammoth-Helena, Thompson-Double, Little Pittsburg, Black Shale, Buck, Wadsworth, Harkness, Nunnally (locally three beds), and Gould. It is, of course, possible that there are other undiscovered beds that are 2 feet thick and that some of the thin beds may locally exceed that thickness. For instance, Squire gives the Atkins (Adkins) bed as 4½ feet thick in the columnar section of the Henryellen basin. The writer, however, found no such bed in that basin and he has the statement of a person thoroughly familiar with that part of the field by extensive prospecting that there are only two beds in the basin—the Harkness and the Mammoth—that are thick enough to mine. With this statement the writer fully agrees. The following description takes up each bed as it occurs in the Henryellen, Little Cahaba, Acton, Helena, and Eureka basins, except the Nunnally and Gould beds, which are continuous throughout the field and for which this method of treatment is not suitable.

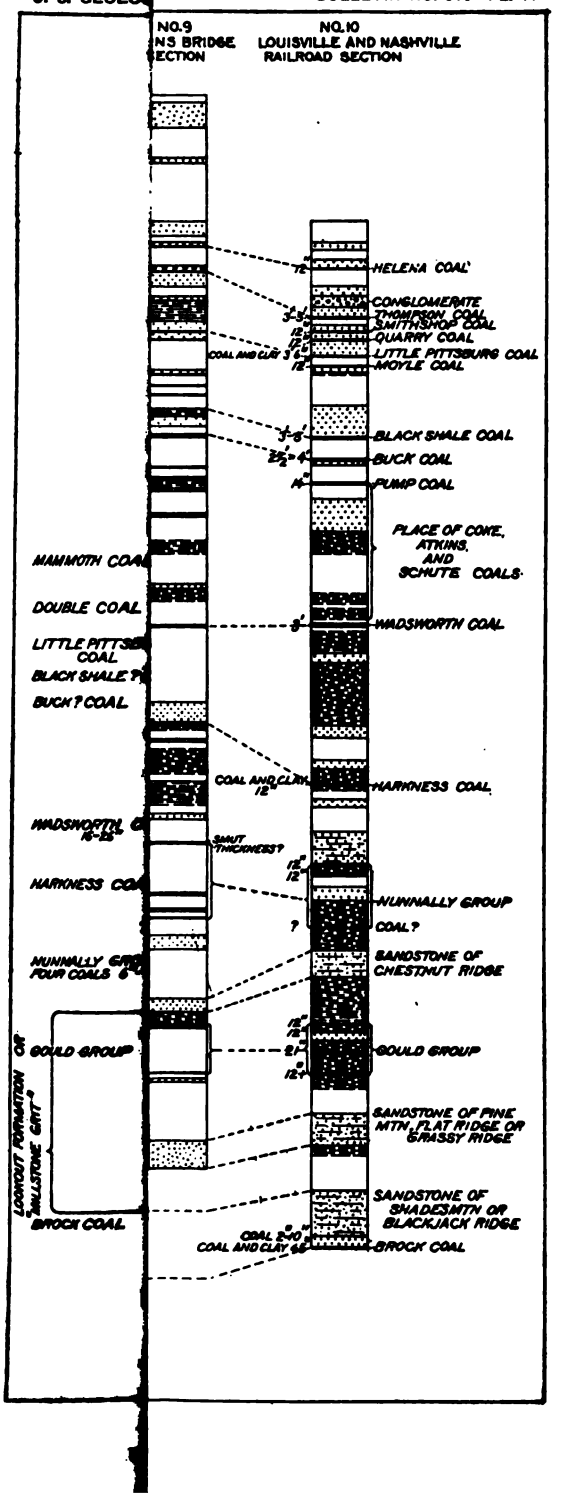
COALS ABOVE THE MAMMOTH-HELENA BED.

There are a number of thin beds above the horizon of the Mammoth-Helena, but only at one point has coal of workable thickness been observed. This is about 1 mile southwest of Henryellen, where a bed about 200 feet above the Mammoth shows the following section:

Section of coal bed 1 mile southwest of Henryellen (No. 1 [a]).

Shale.	Ft.	In.
Coal	1	4
Clay		2
Coal		6
Clay	1	9
Coal	2	4
	6	1

[a] Numbers in parentheses correspond to numbers on the map (Pl. V) showing locations at which observations on the coal beds were made.


NO.9
NS BRIDGE
ECTION
NO.10
LOUISVILLE AND NASHVILLE
RAILROAD SECTION
HELENA COAL
CONGLOMERATE
THOMPSON COAL
SMITHSHOP COAL
QUARRY COAL
LITTLE PITTSBURG COAL
MOYLE COAL
COAL AND CLAY
BLACK SHALE COAL
BUCK COAL
PUMP COAL
PLACE OF COKE, ATKINS, AND SCHUTE COALS
MAMMOTH COAL
DOUBLE COAL
WADSWORTH COAL
LITTLE PITTSB COAL
BLACK SHALE ?
BUCK ? COAL
COAL AND CLAY
HARKNESS COAL
WADSWORTH C
SHUT THICKNESS ?
HARKNESS CO
NUNNALLY GROUP
COAL ?
NUNNALLY GR
FOUR COALS
SANDSTONE OF CHESTNUT RIDGE
GOULD GROUP
GOULD GROUP
SANDSTONE OF PINE MTN, FLAT RIDGE OR GRASSY RIDGE
LOOKOUT FORMATION OR "SANDSTONE GRIT"
SANDSTONE OF SHADE MTN OR BLACKJACK RIDGE
BROCK COAL
COAL 2-10"
COAL AND CLAY
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This bed appears to be in the position of the Yeshic bed of the southern part of the Cahaba field. What is apparently the same bed shows in the Trussville section (Pl. VI) in the road just east of Black Creek, but it is too thin to be of value. Other and higher beds also show in the same section, but they are worthless.

MAMMOTH-HELENA BED.

As stated on page 85, the Mammoth bed of the Henryellen basin is regarded as identical with the Helena of the Little Cahaba, Acton, Helena, and Eureka basins, and the two names are used accordingly.

Henryellen basin.—The Mammoth is the thickest bed in the northern part of the Cahaba field, if not in the whole field. On Black Creek it has the following section:

Section of Mammoth bed on Black Creek.

Shale.	Ft.	in.
Coal and bone	1	10
Coal	3	8
Clay and "rash"		2½
Coal	5	
	10	8½

Farther south the parting near the middle thickens and where the bed has been exposed near the junction of the siding to Henryellen No. 6 mine and the main line of the Southern Railway it has the following section:

Section of Mammoth bed near junction of Southern Railway and siding to Henryellen No. 6 mine (No. 3).

Shale.	Ft.	in.
Coal	5	
Clay		1
Coal		4
Clay		3
Coal	1	
	6	8
Shale	10	
Coal		1
Clay		2
Coal		2
Clay		6
Coal		7
Clay	1	4
Coal	1	8
	4	6

The two benches shown in this section, according to the report of a prospector, persist southwestward to the fault on Hogpen Branch. The same person reports the upper bench to be more or less bony and others in a position to know report the same thing. As the writer had no chance to examine a fresh face of the bed he is unable to make any definite statement on this point.

The average of six measurements of this bed, at points from Black Creek to Henryellen No. 6 mine, is 7 feet 6 inches of coal in the two benches. This is exclusive of partings that could be detected under the conditions of exposure. It is probable that the bed contains 7 feet of minable coal throughout the area underlain by it. The analysis (A) of a sample from this bed collected near Henryellen is given on page 114.

Little Cahaba basin.—A single measurement of the Helena bed at location No. 4, in the Little Cahaba basin, gave a thickness of more than 5 feet gross, without any details as to partings, etc. It is reported to be 11 feet thick at this opening. If that report is true, the thickness is very likely local and due to squeezing, as the rocks are closely folded. The bed may contain 4 feet of minable coal in this basin.

Acton basin.—In the Acton basin the opportunity for examining the Helena coal is very much better than elsewhere in the field, inasmuch as mines are being opened on it at the present time. At one mine the section is as follows:

Section of Helena bed 1¼ miles east of Bains Bridge (No. 5).

	Ft.	in.
Sand and clay	10	
Clay		4
Coal		3
Clay		2
Coal	4	2
Clay		5
Coal	1	9
Clay		1
Coal		3
Total coal bed	7	5

At mine No. 2, three-fourths of a mile southeast of Bains Bridge, the bed has the following sections:

Sections of Helena bed at mine No. 2, three-fourths of a mile southeast of Bains Bridge (No. 6).

A. AT MAIN ENTRY.

	Ft.	in.
Sandstone	15	
Coal	1	
Clay	2	
Coal	1	3
Total coal bed	4	3

B. 100 FEET DOWN THE SLOPE FROM THE MAIN ENTRY.

	Ft.	in
Coal		3
Clay		2
Coal	1	10
Clay		7
Coal	1	9
	4	7

The inference from the preceding three sections is that in this basin the bed is irregular in thickness and character. The average thickness of coal in the three measurements is 50 inches, and 4 feet may be taken as the probable average thickness of this bed in the Acton basin. The composition of the Helena coal in this basin is shown in analysis B (p. 114).

Helena basin.—No measurements were obtained in the Helena basin. Squire, however, gives three measurements in the NE. ¼ sec. 10 and SW. ¼ sec. 2, T. 20 S., R. 3 W.[a] Below are two of these sections:

Section of Helena bed in the SW. ¼ sec. 2, T. 20 S., R. 3 W.

	Ft.	in.
Sandstone.		
Coal	5	11
Slate		6
Coal	2	
Slate.		
	8	5

Section of Helena bed in the NE. ¼ sec. 10, T. 20 S., R. 3 W.

	Ft.	in.
Sandstone.		
Coal	2	6
Slate		3
Coal	1	6
Slate		8
Coal	2	
Slate.		
	6	11

Squire reports the bed at Helena, in the south end of the basin, only 6 inches thick, as exposed in a drift 100 feet in length. It appears, therefore, that this bed is subject to great variations. If this last-mentioned thickness is taken with the other three given by Squire, the average for this basin is 5 feet 6 inches of coal. Five feet would be a conservative estimate.

Eureka basin.—The Helena bed in the Eureka basin is not now open to inspection, except possibly at one point near the highway half a mile southeast of Falliston, where there is a small mine at which the bed is stated to be 5 feet thick. The bed was worked in the north end of this basin years ago, and Squire reports it 4 feet thick, with 2 or 3 inches of bony coal near the middle.[b] No data as to the thickness or character of the bed in the southern part of the basin are at hand. Squire, however, gives a section 4 feet thick with partings as measured in the Dry Creek basin,[c] which lies next south of the Eureka basin. It appears safe to assume, therefore, that the Helena bed will average 3½ feet of workable coal throughout the Eureka basin.

[a] Rept. on Cahaba coal field, 1890, pp. 57, 58. [b] Op. cit., p. 60. [c] Op. cit., p. 77.

THOMPSON OR CONGLOMERATE BED.

Henryellen basin.—In the Henryellen basin the Double bed or its upper bench is supposed to be the equivalent of the Thompson or Conglomerate bed in the southern basins. The lower bench of the Double may be the equivalent of one of the thin beds close below the Thompson bed in the Helena section. At only one point in the basin does this bed appear to be of minable thickness. This is on the Southern Railway, near the junction of the siding to Henryellen No. 6 mine (No. 7). The bed appears to be thick at this place, but was not well enough exposed to be measured.

Little Cahaba basin.—Nothing was learned of the Thompson bed in this basin unless a thin bed apparently 4 inches thick, 50 feet below the conglomerate, is its representative.

Acton basin.—The Thompson is a minable bed in this basin, though the thickness and character do not appear to offer much encouragement to mining at the present time.

Section of Thompson bed 1¼ miles east of Bains Bridge (No. 8).

	Feet.
Conglomerate	5
Sandstone	10
Shale	8
Coal	3
Shale.	

Section of Thompson bed at mine No. 1, two-thirds of a mile southeast of Bains Bridge (No. 9).

	Ft.	In.
Conglomerate	5	
Shale		6
Coal		4
Clay		2
Coal		2
Clay		2
Coal		2
Clay		1
Coal		2
Clay	1	11
Coal, variable	1	6
Total coal bed	4	8

Fifty feet farther down the slope in mine No. 1 the bench of coal above the 12 inches of clay is as follows:

Section of upper part of Thompson bed at mine No. 1.

	Ft.	in.
Coal		1
Clay		½
Coal		1
Clay		1
Coal		1
Clay		1
Coal		2
Clay		½
Coal		1
Clay		½
Coal		1
Clay		1
Coal		1
Clay		¼
Coal		1
Clay		1
Coal		2
	1	4¾

This intimate mixture of coal and dirt in the upper bench makes it worthless without washing. The measurements given above do not afford a reliable basis for judging the thickness and character of the bed in the whole basin. These measurements indicate an average thickness of 2 feet 6 inches of coal, and that is assumed as the thickness of minable coal. The composition of coal from this bed is shown in the table of analyses (p. 114).

Helena and Eureka basins.—The Thompson bed was not seen in the Helena basin. It has been opened on the Louisville and Nashville Railroad, but the openings are now closed. Squire[a] reports that the bed ranges in thickness from 2½ to 12 feet, with an average of 3 to 5 feet of good coal. He also reports that the bed has a bad roof and in places has many layers of smut, which impair its quality. For these reasons attempts to mine the bed have always been unsuccessful. At the north end of the Eureka basin (No. 10) the coal is reported 5 feet thick. At the Coalmont mine, in the southern part of the basin, the bed has the following section:

Section of Thompson bed at Coalmont mine.

	Ft.	in.
Sandstone.		
Coal	2	
Shale		2
Coal	2	10
Sandstone.		
	5	

[a] Op. cit., p. 55.

It seems safe to assume from these reports and measurements that the bed contains 4 feet of minable coal throughout the basins. (See table of analyses (p. 114) for composition of beds at Coalmont.)

LITTLE PITTSBURG BED.

The Little Pittsburg is the next bed below the Thompson or Double that shows any prospect of being workable. The type locality of this bed is at Helena, where it has been opened and worked to some extent near the Louisville and Nashville Railroad. At this point it is 400 feet below the Helena bed.

Henryellen basin.—In the Henryellen basin a bed from 300 to 400 feet below the Mammoth is regarded as the Little Pittsburg. At a prospect on Black Creek (No. 11) 2 feet of solid coal is exposed below shale. The bed may be a little thicker, as the bottom was concealed. Just north of the Trussville road, west of Black Creek, the following section was measured:

Section of Little Pittsburg bed near Trussville road (No. 12).

	Ft.	in.
Shale.		
Coal	1	5
Fire clay		3
Coal		5
Fire clay		8
Shale.		
	2	9

On the Southern Railway, at the east end of the bridge over Cahaba River (No. 13), the bed is 21 inches thick and consists of solid coal, under 20 feet of thick-bedded sandstone. Still farther south, on Snake Branch (No. 14), the bed shows 2 feet 4 inches of solid coal under 20 feet of sandstone. Nothing is known of the coal bed southwest of the last-described point. The bed will probably not average 2 feet of coal in this basin.

Little Cahaba basin.—What appears to be the Little Pittsburg bed shows a good thickness at some points on Coal Bed Branch, on the west side of the Little Cahaba basin. At other points the bed is thin, indicating considerable irregularity in thickness. Below are a number of measurements, the first being near the mouth of Coal Bed Branch.

Section of Little Pittsburg coal near mouth of Coal Bed Branch (No. 15a).

	Inches.
Coal	5-12
Clay	3
Coal	5
	13-20

On the highway a short distance farther north the following section is exposed:

Section of Little Pittsburg coal near Coal Bed Branch (No. 15).

	Ft.	in.
Sandstone	10	
Shale	15	
Coal	1	
Shale	10	
Coal		6
Shale	6	
Coal		3
Clay		3
Coal		2
Clay		3
Coal and clay		2–4
Coal		4
Clay		2
Coal		2
Clay		8
Coal		4
Shale.		
	45	6

The worthless character of the bed is evident. It may be that the upper thin coals represent some of the beds above the Little Pittsburg. Farther north, however, the bed is better, as shown by the following section:

Section of Little Pittsburg bed on the east side of Little Cahaba basin (No. 16).

	Ft.	in.
Sandstone	4	
Coal	3	
Clay		2
Coal		1
Clay		2
Coal		5
Clay	1	
Total coal bed	3	10

On the west side of the basin (No. 17) the bed is at least 3 feet 9 inches thick, but the bottom was concealed and the full thickness could not be determined. Six feet of coal is reported at this point. At another point near by 5 feet of coal is reported. From the above data it seems possible that the Little Pittsburg bed does not average more than 2 feet of coal throughout the area included within its outcrop in this basin.

Acton, Helena, and Eureka basins.—It is a question whether the Little Pittsburg is to be considered a minable bed in these basins. At a single point in the road east of Bains Bridge, a bed of solid coal

2 feet thick, which appears to be in the position of the Little Pittsburg bed, is exposed under a heavy sandstone. At the type locality on Buck Creek, just west of Helena, the following section was obtained from a weathered face near the outcrop:

Section of Little Pittsburg bed near Helena (No. 18).

	Ft.	in.
Shale.		
Coal		10
Clay		1
Coal		2½
Clay		1
Coal		1½
Coal and clay		8
Clay		2
Coal and clay		2
Shale		7
Coal and clay		7
Shale.		
	3	6

An effort was made by Mr. Squire to mine the bed at this point, but it was unsuccessful. If the above section fairly represents the character of the bed, its worthlessness is evident. Squire[a] reports the following section at a test pit near the type locality:

Section of Little Pittsburg coal in sec. 16, T. 20 S., R. 3 W.

	Ft.	in.
Sandstone.		
Coal	1	6
Slate		8
Coal	1	2
Clay.		
	3	4

This indicates a better condition of the bed, but probably it is so variable as to be worthless for mining on a commercial scale.

BLACK SHALE AND BUCK BEDS.

The type locality of the Black Shale and Buck beds is near Helena, where they have been opened and worked to some extent. The attempt to identify them north of the type locality is very unsatisfactory, on account of scarcity of exposures and the number of thin beds occurring between the Little Pittsburg and the Wadsworth coals.

Henryellen basin.—A bed exposed on the Central of Georgia Railway three-fourths of a mile northwest of Henryellen, and having the following section, may be the Black Shale bed.

[a] Op. cit., p. 54.

Section of Black Shale bed (?) on Central of Georgia Railway, three-fourths of a mile northwest of Henryellen (No. 19).

	Ft.	in.
Shale.		
Coal		6
Clay		7
Coal		1
Clay		1
Coal	1	2
Clay		6
Coal		5
Clay.		
	3	4

This bed may be represented by smut on the Trussville road, as shown on section 2, Pl. VI, p. 86. A prospect pit on Black Creek, not seen by the writer, but apparently between what is identified as the Buck bed and the Little Pittsburg bed, may also be on the Black Shale. There are other prospect pits on Snake Branch at about the horizon of this bed, but they were closed and the coal could not be seen.

A coal bed 2 feet thick, exposed by a prospect on Black Creek one-fourth of a mile east of the Central of Georgia Railway (No. 20), is regarded as the possible representative of the Buck bed. What is possibly the same bed shows the following section on the Trussville road, about half a mile west of Black Creek:

Section of Buck bed (?) on Trussville road (No. 21).

	Ft.	in.
Shale.		
Coal		4
Clay		4½
Coal		8
Clay		1
Coal, dirty	1	
Clay.		
	2	5½

The sections given above are the best that were seen in this basin between the Little Pittsburg and the Harkness beds. None show more than 2 feet of coal, and these beds are not minable with profit under present conditions. They may be minable in places at some future day and it does not seem that they should be ignored in estimating the amount of available coal in the basin. It is therefore assumed that the Black Shale and Buck beds will together furnish minable coal in the Henryellen basin equivalent to a bed 2 feet thick, over the area of the Buck bed.

Little Cahaba basin.—Neither the Buck nor the Black Shale bed is known to be of value in the Little Cahaba basin. A bed 21 inches thick in the road on the west side of the basin (No. 22) may be the

Black Shale. Other points at which apparently the same coal was seen are indicated on the map.

Acton basin.—There are many thin beds below the Little Pittsburg in this basin, some of which undoubtedly represent the Black Shale and Buck beds. So far as observed none of these beds have sufficient thickness to be of value.

Helena and Eureka basins.—At the type locality west of Helena (No. 23) the Black Shale bed is reported by Squire to be all coal and 3½ feet thick. One-half mile south of the Louisville and Nashville Railroad the following section of the bed was measured:

Section of Black Shale coal bed one-half mile south of Louisville and Nashville Railroad (No. 24).

	Ft.	In.
Sandstone	5	
Shale	1	
Clay	2	
Coal	4	3
Floor not exposed.		
Total coal bed	4	3

One-half mile farther south a thickness of 4 to 5 feet is reported. No other measurements of this bed were obtained north of Mossboro, where in a railroad cut (No. 25) a bed which may be the Black Shale is exposed, with a thickness of 3 feet 2 inches. The average of all measurements obtained is 3 feet. It is therefore assumed that the Black Shale bed contains 2½ feet of minable coal in the Helena and Eureka basins.

The Buck bed at the mine of the Pratt Cahaba Coal Company, near Falliston (No. 26), is solid coal and ranges from 2 feet 5 inches to 3 feet in thickness. At Mossboro (No. 27) what appears to be the Buck bed has a thickness of only 15 inches. These measurements indicate an average thickness of 26 inches, and 2 feet is therefore assumed as the thickness of minable coal in the Helena and Eureka basins.

COKE BED.

The Coke is a good bed in the southern part of the Cahaba field, but if it is present in the northern part it can not be identified except possibly near Mossboro, on the south boundary of the area under discussion. At this point (No. 28) there is an abandoned mine, apparently in the Coke bed, which shows a thickness of 2 feet 4 inches of coal. No account is taken of this bed in computing the tonnage of the field, as nothing further is known of its extent.

WADSWORTH BED.

So far as known the Wadsworth is the next bed of minable proportions below the Buck bed in this area, except possibly the Coke bed at Mossboro as just described.

Henryellen basin.—In the Henryellen basin the Wadsworth bed does not appear to be thick enough to be mined to any extent except near the south end of the basin on Cahaba River. Near Parsons station, on the Seaboard Air Line Railway, at the north end of the basin, the following section was measured:

Section of Wadsworth bed near Parsons station (No. 29).

	Ft.	in.
Shale		3
"Rash"		1
Coal		5
Parting		⅛
Coal		5
Parting		¼
Coal		9
Parting		¼
Coal		5
Clay.		
Total coal bed	2	1⅝

At location No. 30, a short distance south of No. 29, the coal is only 15½ inches thick immediately under 60 feet of sandstone. These sections do not indicate a workable bed in this part of the basin, nor is it known to be of workable thickness between this locality and the Birmingham-Leeds road. On the west side of Cahaba River, one-half mile above the highway bridge (No. 31), the bed contains approximately 5½ feet of pure coal. On Kanetuck Branch (No. 32), one-half mile south of No. 31, the bed is 2 feet 4 inches thick, all coal. If the conception of the structure in this locality is correct, there is only a small area of workable coal here, inasmuch as the bed would be faulted out one-half mile east of the outcrop. If, however, the thickness existing at locations Nos. 31 and 32 persists for a considerable distance to the north, as may be the case, the Wadsworth bed would contain workable coal worth considering in estimating the general tonnage of the field. Since these points are not certainly determined, the Wadsworth bed is not taken into account in the Henryellen basin.

Little Cahaba basin.—As set forth in the discussion of the general correlation of coals (pp. 82–86), there is difficulty in the identification of the lower coals in this basin on account of the fault which is supposed to exist along its west side. According to the interpretation of

the writer, the bed now mined for coal for use at the waterworks pumping station is the Wadsworth. It is supposed, also, that the same bed was worked at the old mine near the station (No. 33), in which the fault was encountered that led to the abandonment of the mine and the removal to the present location.

The character of the bed at the mine now in operation, 1 mile southeast of the pumping station, is shown by the section below:

Section of Wadsworth bed at pumping station mine (No. 34).

	Ft.	In.
Shale	8	
Coal	2	8
Shale		3
Coal	1	4½
Clay		7
Coal		5
Clay		5½
Coal, variable		6½
Shale.		
Total coal bed	6	3½

The bed at this point is about 250 feet below the conspicuous heavy white sandstone which makes the ridge east and northeast of the pumping station. (Pl. VI, p. 86.) As shown on the map, the bed is slightly displaced by the fault in the locality of the old mine (No. 33). Northeast of this region the identity of the bed is more or less uncertain and nothing is known of its thickness and character. A small showing of coal in a ravine east of the fault, about 1 mile northeast of the pumping station (No. 35) is supposed to be in this bed, and a thin coal bed outcropping in vertical shale toward the north end of the basin, about one-half mile south of the Birmingham-Leeds road (No. 36), is possibly the Wadsworth.

In view of the very meager data concerning the Wadsworth bed in this basin it seems hazardous to venture an estimate of the amount of coal that it carries. The sections obtained in the south end of the Henryellen basin at locations Nos. 31 and 32 afford some basis for judging of its condition in the north end of the Little Cahaba basin. All the facts being taken into account, the bed may reasonably be assumed to contain on the average 2 feet of workable coal.

Acton, Helena, and Eureka basins.—The Wadsworth is known to be of workable thickness along most of its outcrop in the Acton, Helena, and Eureka basins and may be assumed to be workable throughout the area of these basins. On Acton Creek, at the north end of the Acton basin (No. 37) an exposure of what may be the Wadsworth shows 18 inches of coal, and probably the entire bed is at least 2 feet thick. Near Cahaba River, on the east side, one-half mile south of Bains Bridge (No. 38), is an opening in this bed at which 18 inches of

coal is in sight, the bottom not being exposed. The bed is probably 2 feet or more thick. On Cahaba River, farther south, near Langston ford, this bed shows the following section:

Section of Wadsworth bed one-half mile north of Langston ford (No. 39).

	Ft.	in.
Shale	8	
Coal	3	9+
Clay		4?
Coal		3
Total coal bed	4	4

Near the water's edge on the east side of the river at Langston ford the coal is reported at least 2½ feet thick by Mr. Roy, an old resident of the locality. South of Sydenton is the Star Cahaba No. 2 mine, at which the following section was obtained:

Section of Wadsworth bed at Star Cahaba No. 2 mine, south of Sydenton.

	Ft.	in.
Sandstone.		
Shale	2–5	
Coal	2	1
"Rash"		7½
Clay	1	
Shale.		
Total coal bed	3	8½

The bed is said to average 3 feet in thickness. This agrees approximately with the statement of Mr. Squire, who has had much experience in mine surveys in this locality. He considers the average thickness to be 3 feet 3 inches. On account of the anticlines and synclines the outcrop of the bed is repeated three times along the Louisville and Nashville Railroad. There is an imperfect exposure at Tacoa (No. 40), and the bed was originally worked near this point by Frank Wadsworth, from whom it takes its name.

Little is known of the bed south of Tacoa, but an old mine one-half mile west of Roebuck station (No. 41) and an old pit east of the big bend of the Cahaba one mile northwest of Coalmont (No. 42) appear to be on the Wadsworth. One-half mile northwest of Mossboro (No. 43) the bed shows 5 feet of coal. The average thickness of workable coal in this bed in the Acton, Helena, and Eureka basins may be safely taken as 2½ feet. The bed is said to have an excellent roof wherever it has been mined, and it may be considered one of the most valuable in the southern part of the area discussed in this paper.

HARKNESS BED.

Although the type locality of the Harkness bed is on the Louisville and Nashville Railroad northwest of Sydenton, the coal is too thin

to be of value in this area except in the Henryellen and possibly in the Little Cahaba basin.

Henryellen basin.—At the Margaret mine at Davis, 3 miles northeast of Parsons station and about 1 mile east of the territory represented by the map, the bed presents the following section:

Section of Harkness bed at Margaret mine, 3 miles northeast of Parsons.

	Ft.	in.
Shale.		
Clay	1	
Coal		7½
Clay		4½
Coal		7¼
Clay		9
Coal	2	6
Clay	1	8
Total coal bed	4	10¼

Near Parsons station is a prospect pit (No. 44) at which the coal is reported to be of good thickness. Just south of the Trussville road the following measurement was obtained at an old mine:

Section of Harkness bed near Trussville road, one-half mile east of Cahaba mine (No. 45).

	Ft.	in.
Shale	8	
Clay with streaks of coal	1	
Bone		1
Coal		6
"Rash"		1
Coal		8
Clay	1	5
Bone		1
Coal	1	
Clay		4
Coal		1½
Coal, solid	1	2
Coal, crushed (?)	2	6
Clay.		
Total coal bed	7	11½

The lower 30 inches of coal at this point has a peculiar shattered or hackly appearance, as if it had been crushed. The same feature was noted at a pit on the Southern Railway and at intermediate points. It seems likely that this condition is due to some peculiar original constitution of the bench which has been revealed by weathering, rather than the result of crushing due to folding, inasmuch as none of the other coals of the region exhibit such characteristics nor does the Harkness bed at other localities.

This coal has been thoroughly prospected from the Trussville road to Snake Branch, 1 mile south of the Southern Railway, and for nearly the whole distance it shows a workable thickness. In the NW. ¼ sec. 5, T. 17 S., R. 1 E., it has the following section:

Section of Harkness bed in NW. ¼ sec. 5, T. 17 S., R. 1 E. (No. 46).

	Ft.	in.
Coal, with thin streaks of dirt (?)	1	1
Clay	1	2
Coal, crushed	3	10
	6	7

On the Central of Georgia Railway the bed has an unusual amount of bony coal and exhibits the section given below:

Section of Harkness bed on Central of Georgia Railway (No. 47).

	Ft.	in.
Coal	1	
Coal, bony	1	4
Clay	1	
Coal		8
Coal, bony	1	
Coal	1	2
	6	2

On the Southern Railway the bed is considerably diminished in thickness and much less valuable than farther north. The section at this place is as follows:

Section of Harkness bed on Southern Railway (No. 48).

	Ft.	in.
Shale	3	
Coal		2
Clay	1	
"Rash"		8
Coal		9
Clay and coal		5
Coal, crushed, soft		11
Clay.		
Total coal bed	3	11

The deterioration in the value of the coal bed increases to the southwest, and on Snake Branch 1½ miles southeast of Lovick (No. 49) it is broken by so many partings as to be worthless.

Nothing is known of the coal from Snake Branch to Cahaba River, but near the river the bed is considerably improved, as shown by the following section exposed a short distance above the mouth of Hogpen Branch:

Section of Harkness bed near Cahaba River 1½ miles above mouth of Hogpen Branch (No. 50).

	Ft.	in.
Clay	1	
Coal	1	8
Clay and dirty coal	1	7
Coal		9
Clay		5
Coal		1½
Clay	1	
Total coal bed	4	6½

One-third mile farther south another section was taken, as follows:

Section of Harkness bed on north side of Cahaba River near Birmingham-Leeds road (No. 51).

	Ft.	in.
Sandstone.		
Clay, coaly		4
Coal	1	6
Clay		4
Coal		2½
Clay		1½
Coal, dirty, and clay		3
Clay		1
Coal		4
Clay		½
Coal		½
Clay		½
Coal		½
Clay		1
Coal		½
Clay		4
Coal		11
Clay		¾
Coal		¾
Clay		4½
Coal		2
Clay	1	
	6	4½

Still farther southwest, in the SE. ¼ sec. 32, T. 17 S., R. 1 W., the following section was obtained:

Section of Harkness coal in the SE. ¼ sec. 32, T. 17 S., R. 1 W. (No. 52).

	Ft.	in.
Sandstone	25	
Clay		7
Coal	1	10
Clay		3
Coal		3½
Clay		7
Coal		3
Shale.		
Total coal bed	3	9½

At this locality the bed is so dirty and contains so little coal that it is practically worthless. Still farther south, near the center of the east line of sec. 12, T. 18 S., R. 2 W. (No. 53), is the outcrop of a coal bed over 2 feet thick which is probably the Harkness.

The average thickness of coal in 16 measured sections of the bed from the Margaret mine to the south end of the Henryellen basin is 3 feet, and it is assumed that the bed contains that amount of minable coal throughout the basin.

Little Cahaba basin.—As shown in the discussion of correlations (pp. 82–86) and on the map (Pl. V, p. 80), the outcrop of the Harkness bed is probably repeated on the east side of the fault extending from Hogpen Branch to the waterworks pumping station. The following section of the supposed Harkness in this basin was measured in a prospect pit on the Birmingham-Leeds road, 1 mile east of the river:

Section of Harkness bed on the Birmingham-Leeds road, 1 mile east of Cahaba River (No. 54).

	Ft.	in.
Shale	10	
Coal	2	8
Clay	1	
Coal		10
Clay.		
Total coal bed	4	6

Near this point fossil plants were collected which David White regards as probably representing the horizon of the Harkness bed.

About half a mile southwest of this prospect pit is another opening in the same bed which shows the following section:

Section of Harkness bed a little south of the Birmingham-Leeds road, 1 mile east of Cahaba River (No. 55).

	Ft.	in.
Shale	10	
Coal	3	4
Clay		1½
Coal		2
Clay		2
Coal	1	1
Shale or clay		
Total coal bed	4	10½

In the road about half a mile east of the river, near the line between sees. 33 and 34, what was recognized as the Harkness bed is exposed at two points near each other but in opposite sides of a subordinate syncline. At the western exposure the following section was measured:

Section of Harkness bed on Birmingham-Leeds road, one-half mile east of Cahaba River (No. 56).

	Feet.
Shale	
Coal	4
Clay	1
Coal	1
	6

The structure at this locality, as well as the similarity of the coal sections, strongly indicates that the coal beds showing at Nos. 54, 55, and 56 are the same bed. The writer has no knowledge of this bed between the Birmingham-Leeds road and the northeast corner of sec. 18, T. 18 S., R. 1 W. (No. 57). At this point there is an exposure indicating over 1 foot of coal. The position of this bed with respect to the strike of the rocks and with relation to the sandstone mapped one-third mile to the east indicates that it is the Harkness coal. On the west side of the fault, half a mile northwest of the pumping station (No. 58), there is an opening showing 3 feet of coal which, on account of its relation to the beds of the Nunnally group along the river to the west, is regarded as Harkness.

From the foregoing sections it appears not improbable that the Harkness bed contains [illegible] feet of workable coal in the Little Cahaba basin. No data are to hand regarding the bed south of this basin except near the south margin of the area mapped, where it may be thick enough to mine. About [illegible] mile south of Sanford (No. 59) a bed in the position of the Harkness shows a thickness of 27 inches, and about half a mile farther south (No. 60) the same bed is 40 inches thick. The bed south of the Little Cahaba basin is not taken into account in estimating the amount of coal in the area under consideration.

NUNNALLY GROUP OF COALS.

It seems best to treat as a group the apparently varying number of coal beds occurring in the zone that includes the Nunnally bed of the type locality on the Louisville and Nashville Railroad, one-half mile northwest of Sydenton; for it would be very difficult and uncertain, if not impossible, to identify any individual bed as the Nunnally throughout the northern part of the field. The group includes the "Five group" of Squire, the type locality of which is apparently near the center of sec. 18, T. 20 S., R. 3 W., where five thin beds are exposed near the road between Genery Gap and Helena. On the Birmingham-Leeds road just west of the Cahaba River bridge no less than six thin beds of this group are exposed. The lowest of these is mapped as the Nunnally of the type locality from the south margin of the field northward to the Birmingham-Leeds road. From that point to the north end of the field the next upper bed has been mapped, but it is by no means certain that the correlation implied in this mapping is correct. The mapping, however, serves to connect the group of coal beds throughout and to show the approximate position and extent of its outcrop.

This group underlies all the basins, and consequently its distribution is treated for the whole field and not by individual basins, as has been done in the case of the higher beds. Except for a small area south of Bamford, the workable coals of this group are roughly limited on the north by the Birmingham-Leeds road and on the south by Patton Creek. Within these limits one or more of the beds are well developed and contain much good coal. In a single locality, about 1 mile south of the Acton ford, there are three workable beds, but at no other place are there known to be more than two workable beds. The three beds at the above-mentioned place are, for convenience, designated the Upper, Middle, and Lower Nunnally.

UPPER NUNNALLY BED.

The only complete exposure of the Upper Nunnally bed is at a prospect pit three-fourths of a mile south of the Acton ford, south of the river and near the bank (No. 61). Here the bed contains 2 feet of coal between layers of sandstone. Though this bed is undoubtedly represented by some of the thin coals north of this point, no bed in a corresponding position thick enough to work has been observed, and hence it is ignored in estimating the resources of the field.

MIDDLE NUNNALLY BED.

The Middle Nunnally is known to be a valuable bed locally, and it may have a greater workable extent than is now recognized.

On the west side of Owens Mountain, on the Trussville road (No. 62), it shows 1 foot 7 inches of coal overlain by 5 inches of dirty coal. About 25 feet below this exposure are three small beds 2 to 6 inches thick. The Middle Nunnally bed was measured on the Southern Railway half a mile east of Lovick, where it exhibits the following section:

Section of Middle Nunnally bed on Southern Railway one-half mile east of Lovick (No. 63).

	Ft.	in.
Shale	1	
Coal		4
Shale and clay	3	
Dirty coal		2
Clay		5
Coal		4
Clay		7
Coal		11
Clay		1½
Coal		6
Clay		4
	7	8½

On the Birmingham-Leeds road a short distance west of Cahaba River this bed shows the following section:

Section of Middle (?) Nunnally coal bed on the Birmingham-Leeds road west of Cahaba River (No. 64).

	Ft.	in.
Coal		9
Clay	2	3
Coal	1	2
	4	2

The general worthlessness of this group of coal beds north of the Birmingham-Leeds road is shown by the sections given above. South of the road the Middle Nunnally bed improves greatly, as shown by the following section obtained in the SW. ¼ sec. 32, T. 17 S., R. 1 W.:

Section of Middle Nunnally bed in the SW. ¼ sec. 32, T. 17 S., R. 1 W. (No. 65).

	Ft.	in.
Sandstone.		
Coal	3	1
Coal, bony	1	
Coal	1	11
Clay.		
	6	

About 2 miles farther southwest on the east bank of the river, in the NE. ¼ sec. 12, T. 18 S., R. 2 W., the section below was measured.

Section of Middle Nunnally bed in the NE. ¼ sec. 12, T. 18 S., R. 2 W. (No. 66).

	Inches.
Sandstone.	
Coal	3 4
"Rash"	2
Coal	7 9
Clay	7 8
Coal	3
Clay	6 7
Coal	28
	56 61

The bed holds this section for one-fourth mile southwest of the river and then begins to deteriorate. Half a mile southwest of the point at which the preceding section was obtained it has thinned to the following section:

Section of Middle Nunnally bed in the SW. ¼ sec. 12, T. 18 S., R. 2 W. (No. 67).

	Inches.
Coal	14
Clay	1
Coal	6
Clay	2

The writer has no knowledge of the Middle Nunnally as a workable bed between the locality just described and a point three-fourths of a mile south of the Acton ford. In the latter locality, near the south bank of the river, is a thick bed, which is supposed to be the same as that described above. There are two exposures half a mile apart at which the following sections were obtained:

Section of Middle Nunnally bed one-half mile south of the Acton ford, No. [illegible]

	[illegible]
Shale	[illegible]
Coal	[illegible]
Parting	[illegible]
Coal	[illegible]
Parting	[illegible]
Coal [illegible]	
Total [illegible]	[illegible]

Section of Middle Nunnally bed three-fourths of a mile southwest of the Acton ford, No. [illegible]

	[illegible]
Sandstone	[illegible]
Coal	[illegible]
Parting	[illegible]
Coal	[illegible]
Shale	[illegible]
Coal	[illegible]
Clay with [illegible]	[illegible]
Coal	[illegible]
Clay	[illegible]
Coal	[illegible]
Clay	[illegible]
Total [illegible]	[illegible]

Nothing is known of this bed either north or south of the Acton ford, and it is doubtful whether it preserves the thickness shown above for any great distance. The facts at hand indicate that the Middle Nunnally is subject to extreme variations in character and thickness.

LOWER NUNNALLY BED.

The Lower Nunnally, as identified, shows only a streak in the Birmingham-Leeds road. It increases in thickness farther south, and in the SW. ¼ sec. 32, T. 17 S., R. 1 W., near the west bank of the river, shows the following section:

Section of Lower Nunnally bed in the SW. ¼ sec. 32, T. 17 S., R. 1 W., near the west bank of Cahaba River (No. 70).

	Ft.	in.
Shale	5	
Coal, variable	1	5
Clay	4	
Coal		4
Clay		2½
Total coal bed	5	9

It improves still farther south, and near the river in the SE. ¼ sec. 1, T. 18 S., R. 2 W., has the following section:

Section of Lower Nunnally bed near Cahaba River, in the SE. ¼ sec. 1, T. 18 S., R. 2 W. (No. 71).

	Ft.	in.
Shale	10	
Coal	2	
Clay		3
Coal	1	
Parting		1
Coal	1	
Total coal bed	4	4

Half a mile southwest of the above-described point (No. 72) the bed is 4 feet thick, with a 3-inch parting of clay and "rash" near the middle. Half a mile farther south, near the west side of sec. 12, in the same township and range (No. 73), the bed is 30 inches thick, all coal.

In the northeast corner of sec. 13, T. 18 S., R. 2 W. (No. 74), what is believed to be the Lower Nunnally is again brought to the surface on the east side of the fault. At this point it is 28 inches thick. If the interpretation of the structure and identification of the coals are correct, the Nunnally beds must outcrop east of the fault in the tract between it and the Harkness bed, as mapped. Since nothing is known of the coals except at the point just described

and possibly one or two others in the immediate vicinity, the Nunnally beds are not mapped in this tract.

The outcrop of the Lower Nunnally has been traced carefully by prospectors southward almost continuously to the Acton ford, but the writer has no information as to its condition except at a few points. One-half mile south of the waterworks pumping station the bed is exposed in a pit and has the following section:

Section of Lower Nunnally bed one-half mile south of the pumping station (No. 75).

	Ft.	in.
Shale.		
Coal	1	8
Clay		10
Coal	1	
	3	6

At a pit about 1 mile south of the pumping station (No.76) the bed is 2 feet thick. About 1 mile northeast of the Acton ford, on the east side of the river, the coal bed has the section given below:

Section of Lower Nunnally bed 1 mile northeast of Acton ford (No. 77).

	Ft.	in.
Coal		1
Clay		2
Coal		1
Clay		2
Coal		1
Clay		3
Coal		4
Clay		1
Coal	2	
	3	3

At this point there is a bed 1 foot thick 15 to 20 feet below the Lower Nunnally, and above it the outcrops of two coal beds show in the road. At the Acton ford the bed has the following section:

Section of Lower Nunnally bed at Acton ford (No. 78).

	Ft.	in.
Shale.		
Coal		1
Shale		4
Coal		1
Shale, variable		4½
Coal	3	8
Shale.		
	4	6½

One-half mile southwest of the Acton ford there are two other openings, at which the bed exhibits sections practically identical with the preceding. Two miles farther southwest, near Patton Creek, the following section was measured:

Section of Lower Nunnally coal near Patton Creek (No. 79).

	Ft.	in.
Shale.		
Coal		6
Clay		10
Coal		9
Clay, variable		2½
Coal, variable	1	6
	3	9½

The bed is traceable farther southwest and is reported to be 7 feet thick at a point 1½ miles southwest of Patton Creek (No. 80). The bed is not exposed, and the writer has no way of verifying the report, but it is regarded as very doubtful. This bed can be pretty surely traced to an opening near the Louisville and Nashville Railroad, the type locality, at which the following section is disclosed:

Section of Lower Nunnally coal near the Louisville and Nashville Railroad (No. 81).

	Ft.	in.
Coal		6
Clay		2
Coal		6
Shale	25	
Coal	1	
Shale.		
	27	2

Whether the lower bed shown in the preceding section is the original Nunnally the writer could not ascertain with certainty. A still lower bed is reported on the Nunnally place, but no exposure could be seen at the time of the writer's visit, and no information as to its thickness and character could be obtained. As stated on a preceding page, there are five thin beds of this group exposed 2 miles southwest of the Louisville and Nashville Railroad (No. 82), and this has probably given rise to the expression "Five group" used by Squire for the Nunnally group. About 1½ miles south of Bamford (No. 83) one of the beds of the group is reported 24 inches thick, but the report could not be verified. With this possible exception, no bed of value is known in the group south of Patton Creek.

The average thickness of coal in all the good sections of the Lower Nunnally bed from the Birmingham-Leeds road to Patton Creek is 2 feet 8 inches. No effort is made to compute the coal of the other beds separately, because their workable areas appear to be so irregular as to defy reliable calculation. Since they are known to contain some workable coal, however, it is arbitrarily assumed that

the amount of such coal will equal 1 foot added to the thickness of the Lower Nunnally bed throughout the area in which it is regarded as workable, making, for the purpose of computation, an average thickness of 3 feet 8 inches for that bed.

GOULD GROUP OF COAL BEDS.

In the interval between the sandstone of Chestnut Ridge and that of Grassy Ridge lie a number of coal beds which are mostly thin, but which generally contain one bed of workable thickness. One bed of this group was originally mined by William Gould, near the present Star Cahaba No. 1 mine, about 1 mile west of Sydenton. From this circumstance the bed has been named the Gould bed, whence the name Gould group. The number of beds observed in the group at various localities is shown in the columnar sections (Pl. VI, p. 86). Whether it is everywhere the same bed of the group that is workable or whether one is workable here and another there is a question that can not be answered at present, though on the map a single bed is shown to indicate the continuity and general position of the group.

A bed belonging to this group is 14½ inches thick 2 miles north of Parsons station (No. 84), where it is immediately overlain by the sandstone of Chestnut Ridge. In the cut on the Seaboard Air Line Railway at the road crossing 1 mile southwest of Parsons (No. 85) two of the lower beds of the group, each only 6 to 8 inches thick, are exposed. On the Trussville road near the crest of Chestnut Ridge (No. 86) the main bed is solid coal 2 feet thick. No measurements of the bed and only two or three observations were obtained on it between this point and the Ratliffe mine, 2 miles southwest of Lovick, where the section is as follows:

Section of Gould coal at Ratliffe mine, 2 miles southwest of Lovick (No. 87).

	Ft.	In.
Sandstone	15	
Coal		6
Parting		⅛
Coal	1	9
Clay	1	
Total coal bed	2	3⅛

Practically nothing is known of the thickness and character of this coal from the Ratliffe mine southward to Rocky Ridge Church. About 1 mile north of New Hope (No. 88) coal smut was seen that probably is made by this bed, and coal is reported at three other points within a mile farther north. One-half mile south of Rocky Ridge Church is a prospect pit (No. 89), now closed, at which the coal bed is reported 3 feet thick. In the Little Valley syncline, 1½

miles west of Rocky Ridge Church (No. 90), the Gould bed is 18 inches thick. Two miles north of the Louisville and Nashville Railroad (No. 91) is a prospect pit at which 1 foot of coal is visible and 2 feet or more indicated. Just north of the railroad (No. 92) 2 feet is shown in a pit. At location No. 93, just west of No. 92, one of the lower beds of the group has been opened in shale. It shows 18 inches of coal and is possibly 2 feet thick. At the Star Cahaba No. 1 mine, 1 mile south of the railroad, the following section was measured:

Section of Gould bed at Star Cahaba No. 1 mine.

	Ft.	In.
Shale		4
Coal	4	
"Rash"		8
Clay		5
Shale	2	
Total coal bed	5	1

In this mine the bed shows great variations of thickness, as shown below:

Thickness of the Gould bed at Star Cahaba No. 1 mine.

	Inches.
Outside of mine	18
At pit mouth	25
50 feet in slope	23
100 feet in slope	30
200 feet in slope	48

It is said that this is about the range in thickness, though in places the bed reaches 5 feet. The bed appears to be without partings and to have a good roof.

At Bamford is another small mine on this bed. The coal is 20 inches thick at the pit mouth and is said to range from 18 to 36 inches, with an average of 26 inches, all coal. At Bamford a greater number of beds of this group was observed than elsewhere (Pl. V, section Q–R), and there has possibly been a repetition by folding or faulting, which is indicated by the offset in the crest line of Chestnut Ridge.

By taking into consideration all the observations and reports it appears not improbable that the Gould bed will average 2 feet of workable coal from the Trussville road to the south margin of the area discussed in this paper.

AMOUNT OF COAL IN THE AREA.

In the computation of the amount of available coal in this area only the coal is included that occurs in beds containing on the average 2 feet or more of coal exclusive of partings. No bed having a smaller average is regarded as workable. The average thickness of the several minable beds is stated in the preceding descriptions. It is assumed that the averages computed from the measurements made on the outcrop will hold under ground as far as the fault that bounds the field

on the southeast and limits the extension of the coal beds in that direction. A layer of coal of density 1.35, 1 foot thick and an acre in extent, contains in round numbers 1,800 tons. That factor is used in this calculation. Most of this coal lies at a depth not exceeding 4,000 feet. The Gould bed, however, may exceed this depth over small areas in the deepest parts of some of the basins.

Below are given in tabular form the acreage and gross tonnage of the minable beds:

Acreage and tonnage of coal in the northern part of the Cahaba basin.

	Average thickness.	Extent.	Amount.
Mammoth-Helena bed:	*Feet.*	*Acres.*	*Short tons.*
Henryellen basin	7	3,200	40,302,000
Little Cahaba basin	4	100	720,000
Acton basin	4	484	3,524,000
Helena basin	5	234	2,106,000
Eureka basin	3½	2,067	1,302,200
Thompson bed:			
Acton basin	2½	910	4,095,000
Helena basin	4	457	3,290,400
Eureka basin	4	2,404	17,308,800
Little Pittsburg bed:			
Henryellen basin	2	4,068	14,644,800
Little Cahaba basin	2	621	2,235,600
Acton basin	2	1,261	4,539,600
Black Shale and Buck beds (Henryellen basin)	2	5,261	19,139,600
Black Shale bed (Helena and Eureka basins)	2½	3,510	15,895,000
Buck bed (Helena and Eureka basins)	2	4,105	14,778,000
Wadsworth bed:			
Little Cahaba basin	2	3,556	12,801,600
Acton, Helena, and Eureka basins	2½	8,214	36,963,000
Harkness bed:			
Henryellen basin	3	7,698	41,569,200
Little Cahaba basin	2½	4,992	22,464,000
Nunnally bed	3¾	14,281	95,254,600
Gould bed	2	55,908	201,268,800
Total		123,331	565,920,100

CHARACTER AND COMPOSITION OF COALS.

The coals of the Cahaba field are all bituminous, the average composition being 2½ per cent moisture, 59 per cent fixed carbon, 32 per cent volatile matter, 6 per cent ash, and 1 per cent sulphur. In fixed carbon they are about the same as the coals of the Warrior field, in volatile matter they are higher, and in ash and sulphur they are lower. They are a little higher in calorific power than the Warrior coals and a little lower than the coals of the New River and Kanawha field of West Virginia. They are excellent steam and domestic coals

Some of the earliest coking operations in the State were located along the Louisville and Nashville Railroad, coal from the Helena, Wadsworth, and Gould beds being used to produce coke for the Oxmoor furnace. Coke from the two beds last mentioned is said by Squire to be of excellent quality. On account of the higher proportion of volatile matter in these coals, however, the yield of coke is less than from the Warrior coals, so that coking them is unprofitable, and they are not coked at present.

Below is a table of analyses showing the composition of mine samples from the principal beds of the field. The number of samples collected is small because the opportunities for obtaining fresh samples were few. The analyses were made by F. M. Stanton at the United States Geological Survey fuel-testing plant at St. Louis. The samples were obtained by channeling the bed from top to bottom and rejecting such impurities as are rejected in mining. About 50 pounds of coal was thus cut from a fresh working face and reduced by pulverizing and quartering to a quart sample. This was sealed in a galvanized-iron can, in which it was transmitted to St. Louis. It is believed that by these means analyses were obtained that nearly represent the actual composition of the coal as it is mined. A number of other analyses are published in Squire's report on the Cahaba field.

Analyses of coal samples from the Cahaba coal field, Alabama.

	A.	B.	C.	D.	E.	F.	G.	H.	I.
Laboratory No.	3460.	3771.	3769.	3745.	3744.	3770.	3484.	3499.	3644.
Analysis of sample as received:									
Prox. Moisture	2.51	2.74	3.59	2.75	2.60	3.65	3.39	1.98	2.12
Prox. Volatile matter	33.81	33.34	33.18	32.56	34.21	33.74	30.69	30.66	28.15
Prox. Fixed carbon	56.85	58.22	58.67	58.46	60.01	58.86	57.08	58.95	61.50
Prox. Ash	6.83	5.70	4.56	6.23	3.18	3.75	8.84	8.41	8.23
Ult. Sulphur	.48	.44	1.08	.87	.66	.48	2.34	1.09	1.98
Ult. Hydrogen	.....	5.20	5.13	5.08	5.32	5.48	5.18	4.94	.....
Ult. Carbon	.....	77.96	77.57	76.55	78.62	80.12	73.81	76.03	.....
Ult. Nitrogen	.....	1.52	1.23	1.12	1.32	1.51	1.53	1.68	.....
Ult. Oxygen	.....	9.18	10.43	10.15	10.90	8.66	8.30	7.85	.....
Calorific value determined:									
Calories	.....	7,722	7,805	7,699	8,026	7,976	.....	7,563	.....
British thermal units	.....	13,990	14,049	13,858	14,447	14,537	.....	13,613	.....
Loss of moisture on air drying	1.00	.90	2.00	1.10	1.10	2.40	1.80	.80	.80
Analysis of air-dried sample:									
Prox. Moisture	1.53	1.86	1.62	1.67	1.52	1.28	1.62	1.19	1.33
Prox. Volatile matter	34.15	33.64	33.86	32.92	34.59	34.56	31.25	30.90	28.38
Prox. Fixed carbon	57.42	58.75	59.87	59.11	60.68	60.32	58.13	59.43	62.00
Prox. Ash	6.90	5.75	4.65	6.30	3.21	3.84	9.00	8.48	8.29
Ult. Sulphur	.....	.44	1.10	.88	.67	.49	2.38	1.10	2.00
Ult. Hyrogen	.....	5.15	5.01	5.01	5.26	5.34	5.07	4.89	.....
Ult. Carbon	.....	78.67	79.16	77.40	79.50	82.09	75.17	76.64	.....
Ult. Nitrogen	.....	1.53	1.25	1.13	1.33	1.55	1.56	1.69	.....
Ult. Oxygen	.....	8.46	8.83	9.28	10.03	6.69	6.82	7.20	.....
Calorific value determined:									
Calories	.....	7,791	7,964	7,764	8,115	8,180	.....	7,613	.....
British thermal units	.....	14,117	14,336	14,012	14,607	14,812	.....	13,722	.....

A. Mammoth bed, 2 miles southwest of Henryellen.
B. Helena bed, in Acton basin, north of Helena.
C. Thompson or Conglomerate bed, in Acton basin, north of Helena.
D. Thompson or Conglomerate bed, at Coalmont.
E. Buck bed, at Falliston.
F. Wadsworth bed, near Sydenton.
G. Harkness bed, at Davis.
H. Gould bed, at Lovick.
I. Gould bed, 1 mile west of Sydenton.

MINING CONDITIONS.

As previously stated, it will be comparatively easy to reach by railroad almost all points at which mines might be opened to advantage in this part of the field; the problem of transportation is therefore simple.

Probably most of the mining in the field will be done from the outcrop. For all the minable beds except the Gould a haul of less than 3 miles will be required in mining to the boundary fault on the southeast. It is only in the Gould also that a depth exceeding 4,000 feet may be reached over small areas in the deepest parts of the various basins.

As usual in the coal fields of Alabama, the roof and floor of the coal beds are firm, giving but little trouble in mining. The mines are never dangerously gaseous, nor is water particularly troublesome except in times of unusual rains.

DEVELOPMENTS.

At present only six mines are operating in this field. At two of these the production is small, being hauled away in wagons. The other four ship coal by rail, but are not large producers. One of these, the Henryellen No. 6, owned by the Tennessee Coal, Iron and Railroad Company, is working the Mammoth bed 2 miles southwest of Henryellen; the second, the Star Cahaba No. 1, owned by the Star Cahaba Coal Company, is working the Gould bed 1 mile west of Sydenton; the third, the Coalmont mine, owned by the Gray Eagle Coal Company, is working the Thompson bed at Coalmont; and the fourth, owned by the Pratt Cahaba Coal Company, is working the Buck bed at Falliston. Henry De Bardleben, who has for many years been active in the development of this field, is now opening some new mines in the Helena and Thompson beds in the Acton basin which will probably produce a large amount of coal. Much coal has been mined from the Mammoth bed in the past at Henryellen and farther north, but at present all mines except the Henryellen No. 6 either have been abandoned or shut down. For fifteen years previous to 1890 the Helena bed was worked on a considerable scale in the north end of the Eureka basin by the Eureka Company, which used the coal for coke at the Oxmoor furnace. The Wadsworth bed has been worked by different persons at various times. Years ago the bed was worked by Frank Wadsworth at Tacoa station, and during the war it was mined by Woodson & Gould near the railroad bridge on the east side of Cahaba River. More recently the Wadsworth bed has been mined rather extensively at Sydenton by the South Birmingham Coal and Iron Company. Immediately after the war the Gould bed was worked by William Gould at the type locality 1 mile west of Sydenton. The total amount of coal mined in these operations probably has not been very great. These historical statements for the region west of Helena are made on the authority of Mr. Squire, either in verbal statements or in his report, already cited.

COAL INVESTIGATION IN THE SALINE-GALLATIN FIELD, ILLINOIS, AND THE ADJOINING AREA.

By Frank W. DeWolf.

INTRODUCTION.

The area here described is near the southwest edge of the Eastern Interior coal field, lying mostly in Illinois, but extending also into Indiana and Kentucky. Its boundaries are slightly beyond those of the Eldorado and New Haven quadrangles, and it measures 30½ miles from east to west and 18½ miles from north to south, thus including approximately 550 square miles. Parts of four counties in Illinois—Saline, Gallatin, White, and Hamilton—are comprised within the area.

Coal production in this region is increasing so rapidly that geologic work carried on here assumes an important economic aspect. The rapid development of this part of the coal basin is due to the excellent quality of the fuel, its extensive distribution, and favorable mining conditions. The production to date has been entirely in the Illinois portion of the area and until the last year only in Gallatin and Saline counties. White County also is now producing. In 1906 the area included in this report produced 314,927 tons, a gain of 115 per cent over 1905.[a] Coal mining in the Eldorado quadrangle is facilitated by the presence of several railroads; the New Haven quadrangle has none. The whole area, however, has so little relief that it can be easily reached by railroads where desired.

This preliminary statement of geologic field work performed during three autumn months of 1906 is the first published report for this area since 1875,[b] though adjoining areas in Indiana[c] and Kentucky[d] have received later attention. The two quadrangles here described are the first of a series extending across the southern Illinois coal field, the mapping of which will be completed in the near future. The topographic and geologic work is being executed in cooperation by the Illinois Geological Survey and the United States Geological Survey. Information in regard to additional quadrangles on the west will also be included in the final report.

[a] Mineral Resources U. S. for 1906, U. S. Geol. Survey.
[b] Geol. Survey Illinois, vol. 6, 1875.
[c] Rept. Indiana Dept. Geol. and Natural Resources, 1899, pp. 1399, et seq.
[d] Repts. Inspector of Mines of Kentucky. 1893, etc.

The writer is indebted to Stuart Weller and David White for their assistance in correlating the rocks of the region and to George H. Ashley for suggestions in the office. Such value as this report possesses is due largely to the kind cooperation of those coal companies which have placed drill records and other data in the hands of the Survey. To many well drillers and other persons thanks are cordially given for numerous services.

SURFACE RELIEF AND DRAINAGE.

Mining conditions in this field are rendered favorable on the whole by the moderate surface relief. Though the altitudes vary from 340 to 600 feet above sea level, most of the area lies between 365 and 420 feet. The drainage is tributary to Ohio River directly or through the Wabash, Little Wabash, and Saline rivers and their branches. It is deficient in a large area, especially along the Wabash, but considerable reclamation is promised by systematic ditching now in progress.

The topography is of two types—uplands and bottoms. Prominent hills of the New Haven quadrangle are indicated on Pl. VII. Bottom lands constitute about two-thirds of the area of the New Haven quadrangle and about one-third of the Eldorado.

The detailed topographic character of the area and the distribution of timber, houses, roads, and land lines are indicated on the colored contour maps of the Eldorado and New Haven quadrangles.[a] Pl. VIII (p. 120) shows relief and altitude above sea level by contour lines, each of which passes through points of equal altitude on the land, one being drawn for every 20 feet of increase in elevation.

GEOLOGY.

INTRODUCTION.

The economic value of the geologic examination of the various coals of this region lies in determining for each its vertical position, horizontal extent, thickness, quality, structure, and correlation with beds in other areas. Since the study of the region has not yet been fully completed, some of the field observations may be subject to a different interpretation in the final report.

Field work is difficult here because of the presence of glacial and fluviatile deposits which very largely conceal the underlying rocks. The most valuable data were obtained from numerous records of coal borings and a few deeper holes bored for oil. A little information was also derived from water wells. The best exposures of value are those occurring beyond the drift border in the region immediately to the south of this area along Saline River and in the neighboring part of Kentucky.

[a] These maps may be obtained for 5 cents each by addressing The Director, U. S. Geological Survey, Washington, D. C.

STRATIGRAPHY.

GENERAL STATEMENT.

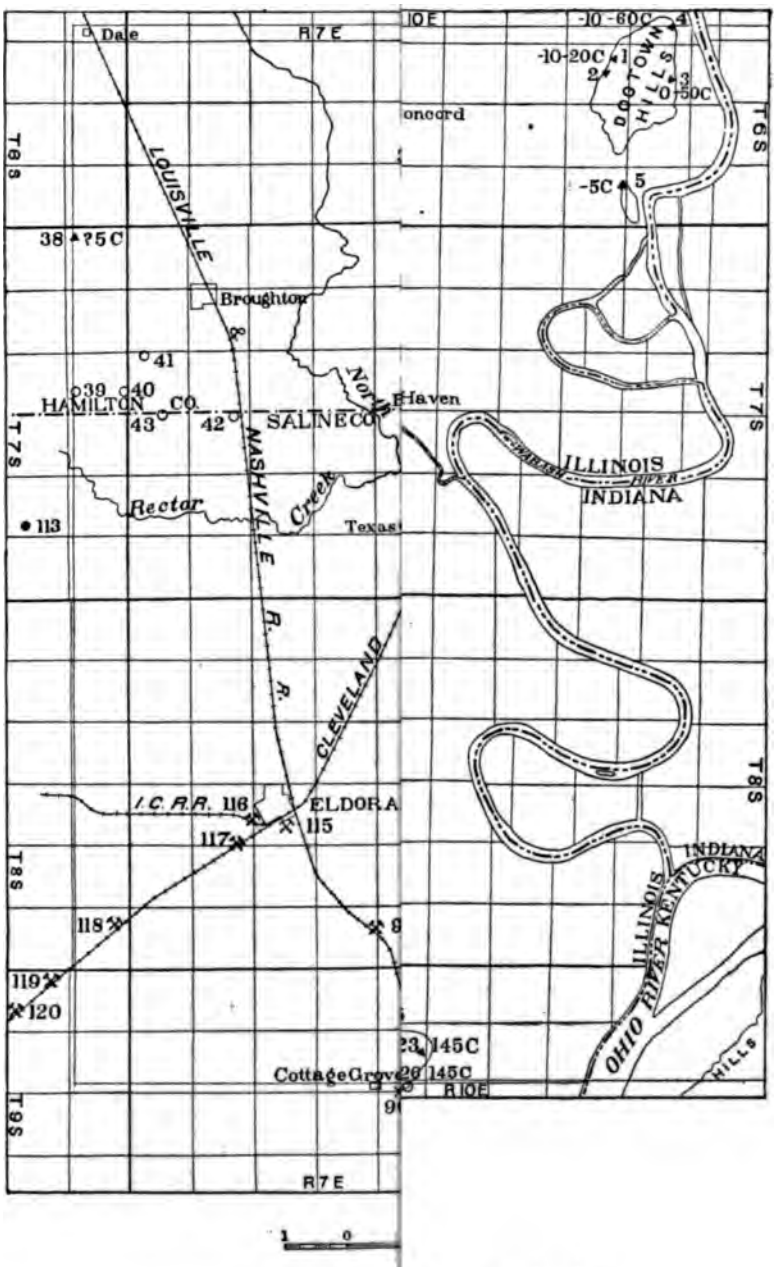
The rocks of this area consist of a varying thickness of fluvial and glacial deposits, overlying alternating shales and sandstones with relatively thin, more or less lenticular beds of limestone, coal, and fire clay. They have been explored to a depth of about 1,500 feet. The hard rocks belong to the Pennsylvanian series of the Carboniferous system.

CORRELATION.

Division of the Pennsylvanian beds of the Kentucky-Illinois area in earlier reports into the "Upper" or "Barren Measures" and the "Lower" or "Productive Measures" was made partly for convenience and partly to conform with earlier subdivisions of the Carboniferous rocks in Pennsylvania. D. D. Owen[a] used as a horizon for this division the Anvil Rock sandstone. In later reports for Illinois A. H. Worthen[b] used, instead, the Carlinville limestone, a bed higher stratigraphically, thought to be identical with the Carthage limestone of Kentucky. It may be questioned whether either of these two horizons or any other has sufficient persistence and prominence to be employed for the division throughout any large part of the Eastern Interior coal basin.

For further convenience in description and correlation the old surveys of Kentucky and Illinois numbered the coal beds upward from the bottom. In the "Lower Measures" the old Kentucky section, however, shows twelve numbered coals, with a few additional beds either designated by letters or not named; while the old Illinois section distinguishes nine numbered coals, and recognizes one of minor thickness to which no number has been applied. The total number of Pennsylvanian coals in the old Illinois section is sixteen. The two stratigraphic columns compiled by the old surveys disagree in the lower portions, and likewise in the upper portions, since Illinois reports place the Carthage limestone not more than 184 feet above coal No. 7,[b] whereas Kentucky reports describe it as occurring 450 feet above the corresponding bed.[c] In the middle portion of the column, however, the coals numbered by Worthen from 8 to 2 seem to be identical with the similar series numbered from 12 to 5 by Owen.[d] No single columnar section can safely be considered representative of conditions over a wide area, since the character of the rocks varies greatly within short distances. As the sections in fig. 2 indicate persistence of certain beds, however, there is reason to hope that study

[a] Kentucky Geol. Survey, vol. 1, 1856, pp. 30-45.
[b] Geol. Survey Illinois, vol. 6, 1875, p. 3.
[c] Geol. Survey Kentucky, vol. 3, 1857, p. 20.
[d] See correlation sheet by C. J. Norwood, in Rept. Inspector of Mines in Kentucky, 1893, p. 96.



5 above sea level.
ext or mine table.

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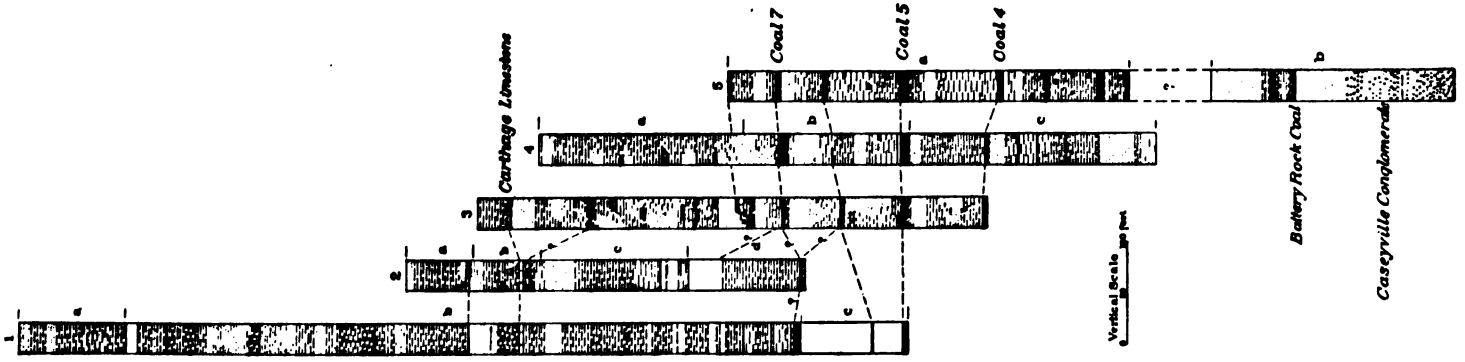


FIG. 2.—Representative columnar sections of Saline-Gallatin coal field, Illinois. These sections are compiled from the following sources (numbers refer to localities indicated by corresponding numbers on Pls. VII and VIII):

1. a. From observations at locs. 31, 32, 33.
   b. From core drillings at locs. 30 and 28.
2. a. From ravines at locs. 8 to 13.
   b. From locs. 49 and 7.
   c. From Shawneetown Hills at locs. 23 and 24.
   d. From well at loc. 26.
3. From numerous tube borings in the southwestern part of the area.
4. a. From tube borings near Junction.
   b. From record and exposures at loc. 79.
   c. From drilling by Broughton Temple at Equality.
5. a. From Gallatin County section by Cox (Geol. Survey Illinois, vol. 6, 1875, p. 202).
   b. From Battery Rock, Ill., and Caseyville, Ky.

of drill records and field evidence will result in a correct correlation of the various horizons. The present use of numbers in the Illinois fields probably does not indicate the true correlation of the coals, though locally over considerable areas the designations are doubtless consistent. It seems advisable in this report to use the numbers so widely accepted in this region, but with the understanding that they are of local significance only and do not imply correlation with beds bearing the same numbers in other areas.

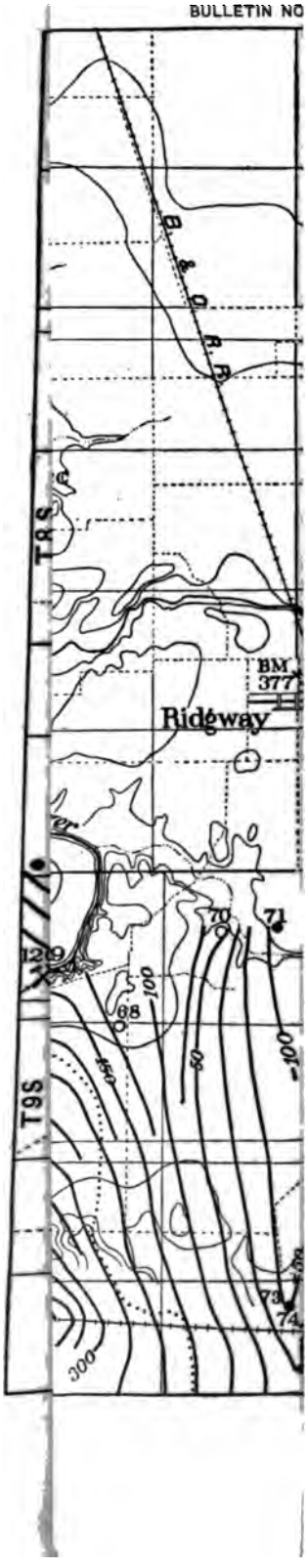
GENERAL DESCRIPTION OF STRATIGRAPHIC COLUMN.

The approximate columnar sections given in fig. 2, compiled from outcrops and borings, indicate the character of the rocks in several parts of the area and show the apparent persistence of certain beds and the local, lenslike character of others. The variations exhibited, however, are due in part to scant and imperfect data. Of the localities referred to in this paper, Nos. 49–112 are shown on Pl. VIII and the others on Pl. VII.

The persistence of the coals from No. 8 to No. 5, inclusive, is notable in the columnar sections. Other beds of special importance stratigraphically are certain limestones. One occurs in section 1, 265 feet above coal No. 7, and is also shown in section 2. Another is indicated in section 3, 190 feet above No. 7, and a third occurs in the same section 45 feet above No. 7. The first of these is tentatively regarded as the Carthage limestone, which is especially important here. It takes its name from a former settlement three-fourths of a mile west of Uniontown, Ky., where the rock is exposed along Ohio River. When fresh, it is hard and blue gray in color, outcrops in vertically-jointed cliffs, and shows a tendency to split into slabs. When weathered, the rock is usually buff or reddish brown. On its surface and through its interior occur abundant brachiopods, crinoid stems, and other fossils. Because of the persistence of these lithologic characters and the similarity of fossil content, limestones at several localities within the area have with some hesitancy been identified with the Carthage.

The distance from this bed to the identifiable coals of the section has considerable economic interest and is a matter of disagreement in the old State reports, as already indicated. It is probable that neither of the old estimates is clearly applicable to this region, although the evidence here presented is not altogether conclusive.

At New Haven a churn-drill well, which commenced on a level with a limestone, probably Carthage, outcropping at loc. 7, reached a thin coal at 260 feet and stopped in a limestone 10 feet lower. No coal referable to No. 7 was passed, though the bottom limestone may



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be the roof of that bed. At Round Pond (loc. 26) a well commencing 160 feet below the outcrop of a limestone, presumably Carthage, reached a 2-foot coal at a distance of 268 feet below that bed, but passed none with the usual characteristics of coal No. 7. In borings near Junction, which strike the first hard rocks 230 feet above coal No. 7, no limestone comparable to the Carthage is reported. These records show either that the interval between the Carthage and the No. 7 coal at these localities exceeds 270 feet, or that there is a lack of development or absence at the first two places of the No. 7 coal and at the last of the Carthage limestone.

A core drill at Norris City (loc. 30) reached a 5-foot limestone 265 feet above coal No. 7. As this limestone is almost identical in character with the Carthage, and carries the same fossils, it may be regarded as that bed, especially because the associated strata are similar to those observed with the so-called Carthage, as indicated in section 2 (fig. 2). The interval between the Carthage and No. 7 coal at Norris City seems therefore to be 265 feet.

Different conditions are recorded around Eldorado. At loc. 102 a thin dark-blue limestone occurs about 225 feet above the horizon of the No. 7 coal, as determined at loc. 103, but at locs. 10, 13, 14, 15, and 16 no limestone is reported at this horizon. One occurs, however, 190 to 210 feet above No. 7 in all the borings in that vicinity which reach its horizon. Its persistence and uniform thickness of about 5 feet suggest that this bed may possibly be the Carthage, though it is separated from the No. 7 coal by an interval 55 to 75 feet less than at Norris City, Equality, New Haven, and Round Pond. Such a change in interval, although improbable, is perhaps further indicated by the imperfect record at Omaha (loc. 48), which reports a hard limestone at 180 feet and coal, comparable to No. 7, 225 feet lower. It seems more likely that the Carthage limestone is lenticular and that it dies out between Norris City and Eldorado or is represented by the thin limestone reported at loc. 102 and others near by. If the identification as Carthage of various limestone beds in this region is correct, its outcrop, representing the boundary between the upper and lower "Coal Measures," would be indicated roughly, beginning near Dogtown, by a line connecting locs. 4, 5, 7, 44, 49, 97, 101, and 103 with an outlyer in the Shawneetown Hills and the area westward to Junction. Future work must demonstrate whether the Carthage limestone can be identified and used as a key rock over this coal field.

Another limestone, as already noted, occurs rather persistently 45 feet above the No. 7 coal. It is generally encountered in borings in the southwest corner of the area and outcrops 1½ miles west of Cottage Grove at loc. 88.

STRUCTURE.

GENERAL STATEMENT.

Although the coals and associated strata of this region are nearly parallel and horizontal, the distances between the strata change from place to place and the beds slope or dip in varying directions and amounts. The determination of the altitude of the coals is important for the reason that economical mining must take advantage of natural slopes for haulage, drainage, and ventilation.

The structure bears an intimate relation to an east-west displacement, just south of the area mapped, which marks the north edge of Gold Hill Range. The amount of this disturbance, which has caused a relative sinking of the strata to the north, is roughly indicated by data obtained at Equality, Cottage Grove, and in the hills to the south.

The lower slope of the range reveals limestones of Mississippian age; the capping is the Caseyville conglomerate. In Prospect Hill this conglomerate has an altitude of about 900 feet, and the altitude of coal No. 5 at this point, if uneroded, would be over 1,425 feet. The same coal 3½ miles farther north, at loc. 84, is nearly 1,300 feet lower, or at an altitude of 145 feet. There is no evidence that this change in level is due to dip, for at both localities the rocks appear to dip southward.

The dips of the coals are predominantly northward, toward the center of the Eastern Interior basin. There are, however, numerous local exceptions. The amount of dip also varies greatly; it exceeds 100 feet to the mile in some localities, but probably averages only half that amount and locally is negligible. There is some evidence of conditions similar to those in the faulted area on the south. Thus at Eldorado, in O'Gara mine No. 8, a 6-foot dike of igneous rock cuts vertically through coal No. 5 and produces a narrow zone of "natural coke." The rock resembles and probably is related to dikes of the Illinois-Kentucky fluorspar district. Elsewhere there are certain abrupt changes in level of the beds, possibly due to faulting, as between Equality and Junction. These conditions are described on page 123. The possible occurrence of such structural changes within the untested areas treated in this report is a source of uncertainty in the determination of the horizontal distribution of the coals.

METHOD OF SHOWING STRUCTURE.

The dips are indicated by a comparison of the figures placed on Pl. VII (p. 118), which show, at various datum points, the measured or calculated altitude of coal No. 5. Additional evidence in the southern portion of the Eldorado quadrangle is shown on Pl. VIII. The structure contours of this map were drawn in the following

manner: The depth to coal No. 5 was either determined from records of test holes and shafts or calculated from the presence in shallow wells or at surface outcrops of other higher strata which could be identified. This figure at each datum point was subtracted from the altitude of the ground in order to obtain the altitude of the coal. Where the coal lies at different altitudes at adjoining points the dip between these was regarded as uniform and points of equal altitude were connected by a contour line. Thus between every two contours there is indicated a dip of 25 feet, except in the southeast corner, where every other line is omitted and the dip is 50 feet between contours. The resultant map may be slightly inaccurate. As the surface elevations were determined by hand level or barometer from bench marks, there are probably small errors. Furthermore, it is possible that in a few places where the depth of the coal was calculated from overlying beds the interval assumed was slightly incorrect. The most important source of error is the assumption that between datum points dips are uniform. It is still reasonably certain that in Saline County the error along any contour line is less than 25 feet, but in Gallatin County, because of lack of data, it may be more.

The dips of the area are readily determined by reference to this map, but attention should be called to the possibility of faulting as an explanation of abrupt changes in altitude in certain localities. Such an explanation is suggested for changes in elevation of the Carthage limestone in the Shawneetown Hills, at locs. 23 and 25.

At Cottage Grove either an anticlinal fold trending east and west or a fault with the downthrow on the south is indicated, for between locs. 84 and 89 there is a change in level of 85 feet in three-fourths of a mile. An abrupt descent of 100 feet also occurs from locs. 93 and 94 to loc. 95, though the distance but slightly exceeds half a mile. Similarly, a descent of about 115 feet occurs from loc. 119 to loc. 120, three-fourths of a mile apart. Underground workings have not yet shown whether this is due to dip or to a fault.

The most interesting locality from this standpoint lies in the southeast corner of the area, between Junction and locs. 75 and 76, where the contours show an apparent dip of 400 feet in 1¾ miles. There is an additional source of possible error here, since the correlations may be incorrect. Probably the test holes in this vicinity, except at locs. 73 and 72, stopped in coal No. 7. The hole at loc. 73 stopped just before reaching it, and that at loc. 72 went through to No. 5. If, however, this interpretation of the records is incorrect and all these test borings reached No. 5, then there is an additional descent of 120 feet between the points mentioned and loc. 73. A considerable proportion of this descent may be due to a fault along a north-south line.

Some such condition is indicated also between locs. 70 and 71, where the levels change 180 feet in half a mile. The information at loc. 70, however, was obtained from a churn-drill boring and may be incorrect.

DESCRIPTIONS OF DATUM LOCALITIES.

The following notes record observations at the localities shown by numbers on the accompanying maps, except those made at coal mines, which are grouped in a later table. Locs. 1 to 48, 113, and 114 are shown on Pl. VII, the others on Pl. VIII, and where possible the calculated altitude of coal No. 5 is shown.

Locs. 1–18.—At these points occurs either the Carthage limestone, an upper bed lying stratigraphically about 50 feet higher, or other closely associated strata. Thin coals usually underlie the limestones. In this region coal No. 7 may be looked for about 275 feet below the Carthage limestone, and coal No. 5 about 120 feet lower. They should occur 50 feet farther below the upper limestone.

Locs. 1–4: The public roads near Dogtown show outcrops of an 18-inch limestone which is underlain by a thin coal at locs. 1 and 2 and which resembles the Carthage bed in fossil content, but corresponds to the higher limestone in thickness. It is from 385 to 395 feet in altitude.

Loc. 5: At the base of the hill occurs a thin coal overlain by a limestone 6 feet thick, which is probably Carthage.

Loc. 6: A 3-foot limestone struck in the well of David Hayes probably occurs stratigraphically considerably above the Carthage.

Loc. 7: At New Haven an exposure occurs in the river bank as follows:

Section at New Haven.

	Ft.	In.
Limestone (Carthage), blue-gray, hard, brittle, fossiliferous	5	
Shale, black	3	
Coal		2
Fire clay	3	
Sandstone and shaly sandstone, soft, fine grained	6	
Shale, sandy	5½	
Sandstone, fine, soft, thin bedded, gray-brown	3	
Low water, Little Wabash River.		

Loc. 8: Near the mouth of Rocky Branch a limestone bed 18 inches thick forms a riffle across the Little Wabash. It carries a somewhat different fauna from the Carthage, which it probably overlies by 50 feet. Above it occurs 6 feet of blue-gray shale bearing iron nodules and below it streaks of coal, embedded in 1 foot of bituminous shale and underlain by blue clay shale.

Locs. 9–18: The same coal and limestone or beds near this horizon are exposed in ravines to the north, accompanied by the beds shown in the columnar sections. A summary follows.

Summary of observations at locs. 9–18.

Loc. No.	Name.	Kind of rock.	Coal.			Remarks.
			Thickness.	Depth.	Altitude.	
			Inches.	*Feet.*	*Feet.*	
9		Limestone, coal	+	0	410	
10	Owen Wilborn	Limestone, coal	+	0	415	
11	J. F. Medlin	Sandstone, coal	18	0	430	Old mine.
12		Limestone, coal	+	0	370	
13		Coal	+	0	415	Old mine.
14	"Devil's Biscuit"	Sandstone [a]				
15	Mrs. Rhoda Grant	Limestone, coal	+	60	360	
16	John Sturm	Limestone, coal	+	60	360	
17	Alex. Questell	Coal	+	125	315	
18	Isaac Bayley	Coal	+	200+	330–	

[a] Thickness of sandstone 20 feet; altitude 380 feet.

Locs. 19–22.—There is some doubt in regard to the stratigraphy of the thin coals and hard rock, presumably limestone, which occur in wells near Cottonwood, and of the sandstones and underlying shale exposed along the hill roads to the north, as at Iron.

Locs. 23–27.—In the region of Round Pond three occurrences of the Carthage limestone furnish a basis for calculating the altitudes of workable coals.

Section at Round Pond.

	Feet.
Limestone, Carthage, altitude 540 feet	5
Concealed	2
Coal, bloom	+
Concealed	24
Sandstone, hard, massive, gray	30
Concealed	35
Shale, argillaceous and sandy, blue-gray	33
Concealed	5
Shale, brown	5
Shale, black, and coal bloom	2
Shale, brown, sandy	20
Concealed to Round Pond	40

Loc. 24: The limestone occurs also at the same altitude near the top of the hill at the road forks.

Loc. 25: A limestone 35 feet below the surface in the well of William Satterly overlies a 2-foot coal and appears on the evidence of lithologic character and fossils to be the Carthage. Its altitude, 195 feet lower than at loc. 23, is probably due to a fault.

Loc. 26: A churn-drill well on the R. L. Millspaugh farm, starting 160 feet below the Carthage limestone, passes through 37 feet of clay and gravel, 71 feet of shale, and 2 feet of coal. While this may be the No. 7 coal without its usual thickness and limestone roof, this test is not conclusive. It is noted under "Stratigraphy" (p. 121)

that near Eldorado, coal No. 7 occurs 200 feet below a limestone which may possibly, but not probably, prove to be the Carthage. If the same interval holds at Round Pond, coal No. 7 should occur where the section is now filled with clay and gravel. Its presence in workable thickness can be determined by a test hole at a point on the hill slope located above this well, so as to avoid the surface clays.

Loc. 27: Though the 25-foot sandstone cliff here has the same elevation as a similar bed in the section at loc. 23, and may indicate absence of dip, the evidence is not strong enough to be trustworthy.

Locs. 28–35.—Near Norris City stratigraphic notes are obtainable from three diamond-drill logs and from hill outcrops, as shown in fig. 2. The altitudes of coal No. 7 in the test borings indicate a dip N. 5° W. of 48 feet to the mile, but the outcrops indicate in the area to the northeast a dip of the same amount N. 26° W. The calculations are based on a cinnamon-brown sandstone and certain thin coals.

Loc. 31: The rocks exposed at the hilltop consist of 10 feet of gray sandstone over 15 feet of brown shale. A few rods to the north, at the crossroads, occur the underlying beds, consisting of cinnamon-brown sandstone 10 feet thick which overlies 20 feet of ferruginous clay shale.

Loc. 32: In a gully west of the road this same sandstone is exposed with its accompanying shale.

Loc. 33: The railroad cut reveals 25 feet of shale and sandy shale, probably occurring 40 feet below the brown sandstone mentioned.

Locs. 34–35: The thin coal 8 feet below the surface at loc. 34 is probably identical with the lower one of two which occur 35 feet apart on the Henson farm at loc. 35 and with the first coal in the boring at loc. 30.

Locs. 36–37.—Beds which are probably well above the Carthage limestone, but of which the horizons are uncertain, occur in the hill west of Norris City and at Gossett. At loc. 36 sandstone and shale partially exposed for 80 feet resemble those beds east of Norris City. At loc. 37 a 10-foot sandstone overlies fire clay which half a mile farther north occurs over a thin coal. A uniform dip from borings south of Texas City to Norris City would bring coal No. 5 about 675 feet below the railroad at Gossett.

Loc. 38.—West of Broughton, on the land of J. T. Barker, a thin coal which outcrops at an altitude of 430 feet is overlain by fire clay and a band of limestone. A 3-foot limestone which lies 32 feet below the coal in a shaft at this point contains typical Carthage fossils and suggests that coal No. 7 should occur 275 feet below it and No. 5 120 feet lower. Since the evidence is not conclusive, coal No. 5 may lie much lower yet.

Locs. 39–43.—Thin coals are struck in a number of wells near Broughton at an altitude about the same as the coal at loc. 38, but it is impossible to identify them or to calculate the depths to workable coals at these points. The occurrences are on the farms of Messrs. Roberts, William Stevens, Golson, C. H. Francis, and Grifin.

Loc. 44.—Southwest of Roland occurs a 3-foot limestone which on lithologic and fossil evidence is probably the Carthage. Coal No. 7 should be reached about 275 feet below it and No. 5 120 feet lower. As this is much less than the depth at Norris City and Omaha, this vicinity would seem to be a favorable place to prospect.

Loc. 45.—Exposures 50 feet higher than at loc. 44 show a sandstone which overlies sandy shale and which probably is identical with that occurring along the Little Wabash, 110 feet above the Carthage limestone. This would indicate a dip of 60 feet from loc. 44 to loc. 45.

Locs. 46–47.—Limestone is reported in wells to the south at an altitude about 35 feet lower than the Carthage at loc. 44.

Loc. 48.—The Omaha well struck at 403 feet a thick coal, which is overlain by 4 feet of limestone and probably is coal No. 7. Another limestone, doubtfully reported 223 feet above it, is possibly the Carthage limestone.

Locs. 49–50.—The Carthage limestone and the upper limestone are probably exposed south and east of Elba, and offer a basis for calculating the altitude of workable coals. At loc. 49 a section of 45 feet is exposed with a 4-foot limestone, probably Carthage, at the base, altitude 343 feet; a 3-foot sandstone at the top; and brown shale between. The beds dip upstream about 1 foot in 40. At loc. 50 a 17-foot section of shale and sandstone shows, 4 feet above the base, a thin bed of limestone and iron ore, at an altitude of 348 feet, but probably lying 50 feet above the Carthage. The dip is to the east, 1 foot in 50.

Locs. 51–69.—The following observations were made between Elba and Equality:

Summary of observations at locs. 51–69.

Loc. No.	Name.	Kind of rock.	Thickness.	Depth.	Altitude.	Geologic horizon.
			Ft. in.	*Feet.*	*Feet.*	
51	—— McCormick	Limestone	.....	52	340	Carthage (?).
52	H. G. Morton	Shale, coal	+	23	375	
53	John Burton	Coal	4	60	340	
54	—— Johnson	Coal	+	31	380	
55	.....	Coal	+	21	330	
56	W. A. Wathen	Limestone	+	25	365	125 or 50 feet over No. 7.
57	F. M. McLean	Limestone	.....	36	350	
58	Broughton Temple	Coal	+	80	280	No. 7.
59	John Nave	Coal	+	90	315	No. 7.
60	—— Percil	Coal	+	90	315	No. 7.
63	.....	Shale	15	0	355	Over No. 6.
64	Frank Hamel	Black shale	+	130	250	Over No. 5.
65	John Davenport	Black shale	+	130	250	Over No. 5.
66	—— Beatty	Coal	+	47	335	No. 6.
68	—— Siebman	Coal	18	65	335	(?)
69	John Hish	Coal	2	0	350	
		Limestone, coal	4	93	257	No. 7.

Loc. 70.—In the 250-foot well of Louis Drone five coals, 18 inches to 10 feet thick, are reported. The thickest bed, probably No. 7, was reached 188 feet down, or at an altitude of 115 feet.

Loc. 71.—Joseph Devous's test hole strikes a coal with limestone roof, probably No. 7, at 380 feet and another, probably No. 5, at 484 feet.

Locs. 72–73.—Test borings of Vandell Mining Company.

Loc. 79.—The following outcrop occurs above the railroad at Equality:

Section at Equality.

	Feet.
Sandstone, coarse, gray, micaceous	10
Shale, light gray	18
Coal, No. 6	2
Fire clay	1
Sandstone and shaly sandstone	4½
Railroad level.	

Loc. 81.—The altitude of an outcrop of the roof limestone of No. 7 coal at Equality, compared with data given on the mine map of the Gallatin Coal Company, shows an interval of 117 feet between coals Nos. 7 and 5.

Loc. 82.—A 156-foot well on the Charles Manel farm probably passes the horizon of coal No. 7, filled with surface clay, and stops just short of coal No. 5.

Loc. 83.—The Pearce well reaches an 18-inch coal, possibly No. 6, at a depth of 77 feet, or an altitude of 283 feet.

Loc. 84.—Coal test boring of Davenport Coal Company.

Locs. 85–87.—Test borings of O'Gara Coal Company.

Locs. 88–89.—West of Cottage Grove a 2-foot limestone, probably 50 feet over coal No. 7, is reached in a well and also outcrops under a 5-foot sandstone and over fire clay.

Loc. 91.—A well reaches coal No. 7 at 365 feet altitude.

Loc. 92.—A. D. Robinson's well reaches a 6-foot coal bed at 124 feet, or at 270 feet altitude. It underlies a limestone and is probably coal No. 7.

Loc. 95.—Test boring of National Mining Company.

Locs. 97–102.—Wells east and south of Eldorado strike limestones at about the Carthage horizon, and these, together with certain coals, seem to indicate a northeasterly dip. A summary follows:

Summary of observations at locs. 97–101.

Loc. No.	Name.	Kind of rock.	Depth.	Altitude.
			Feet.	*Feet.*
97	Tim Sisk	Coal	100	325
98		Limestone	52	348
99	C. A. Jones	Limestone	40	350
		Coal, thin	100	290
100	Philip Collins	Limestone	55	360
101	J. E. Westbrook	Limestone (?)	27	380

Locs. 103–107½.—Test borings of O'Gara Coal Company.

Loc. 108.—Test boring of Wabash Petroleum Company, depth 1,093 feet, dry.

Loc. 109.—Gas well of W. T. Overton.

Locs. 110–114.—Coal test borings of Eldorado Mining Company, Terre Haute, Ind. Records not furnished for use of the Survey.

COAL RESOURCES.

INTRODUCTION.

This region produced 314,927 tons of coal in 1906, a gain of 115 per cent over 1905. Saline and Gallatin counties combined produced 1,069,425 tons in 1906, gaining 58 per cent over the preceding year.

As already described, and as indicated by the columnar sections in fig. 2 (p. 119), coals occur at twenty horizons, at least, but many of these are local in extent and worthless. Only two beds are now mined, Nos. 7 and 5, but inasmuch as three or more lower coals are workable in adjoining areas to the south and east and in other parts of Illinois, it seems likely that drilling may show similar conditions in parts of this region.

EXTENT OF COAL DEPOSITS.

The areal extent of workable coals has been only partly determined, for the persistence of thick beds in the area untested by borings is uncertain; the presence and depth of preglacial valleys is concealed by overlying deposits of glacial drift and of alluvium; and, in addition, it is possible that structural movements may have exposed the coals to preglacial erosion to a degree not now suspected.

In the New Haven quadrangle coals Nos. 7 and 5 will very probably prove to be workable. Their horizons undoubtedly occur under the various hill tracts indicated on Pl. VIII (p. 120), and, in the absence of evidence to the contrary, presumably also under the intervening areas, which are covered by glacial and fluvial deposits. The only information serving to indicate their probable depth below the surface is offered by the outcrops of the supposed Carthage limestone and other related beds at the locations indicated on the map. Though the thickness of the beds here is doubtful, they are generally workable in western Kentucky. They are mined near the southeast corner of the quadrangle at Morganfield, and they are presumably minable also at Mount Vernon, Ind., near the northeast corner, at depths of 625 and 710 feet respectively.[a] In view of these facts and the general thick development of these coals under the Eldorado quadrangle, it seems likely that they are workable under most of this area also unless preglacial erosion lines are deep and extensive.

[a] Core record of Mount Vernon Coal and Mining Company.

Under the Eldorado quadrangle coal No. 7 is probably everywhere present except in a small area along the south margin, as indicated by its outcrop shown on Pl. VIII. It is absent in the southwest corner in borings at locs. 85–87, and has been eroded from the middle of the valley, separating the hills at Cottage Grove and Equality. From the latter place it is absent to a point a little east of locs. 75 and 76, where it reappears. The presence of the coal southward from Equality to the Gold Hill Range is doubtful, because of the probability of structural irregularities and preglacial erosion. Coal No. 5 has similar but somewhat greater extent than No. 7. It is known to extend beyond the margin of the Eldorado quadrangle in the southwest corner. East of Equality it is absent for a short distance between North Fork of Saline River and locs. 75 and 76, also for a short distance farther east. This statement presupposes that the changes in altitude of the rock between Equality and Junction are due, not to a fault, but to uniform dips.

DESCRIPTION OF COALS NOW MINED.

Of the coals now worked, to judge from chemical analyses and from the physical conditions of the beds and their overlying and underlying rocks, No. 5 is more valuable than No. 7, though the latter is nevertheless an excellent bed.

COAL NO. 5 (HARRISBURG COAL).

Coal No. 5, which is identical with No. 9 in Kentucky, is extensively mined at Harrisburg, Eldorado, Equality, and near-by points, as shown by the accompanying table of mines (p. 136). It lies about 100 feet below coal No. 7, and probably about 390 feet below the Carthage limestone. It is about 90 feet above coal No. 4, and 430 feet or more above the Caseyville conglomerate.

The uniform thickness and purity of the bed is characteristic. As observed or reported at 56 places in the area, it averages 4 feet 11 inches in thickness; at only two of these is it less than 4 feet, and at two it exceeds 6 feet. Based on the average thickness of this coal and a specific gravity of 1.3, as determined for one sample, each acre underlain by it contains about 8,700 tons. The coal is either lustrous or dull black, and here and there streaked with "mother coal" or "mineral charcoal." Only a few bands or patches of sulphur are present, and while these are most likely to occur near the top of the bed, they are merely local features. The coal ranges from rather hard and tough to soft and brittle, and has a hackly fracture.

The mining conditions of coal No. 5 are excellent. The roof is a hard shale which usually stays up well without excessive timbering. It is characterized by the presence of pyrite balls, or "niggerheads," and more rarely is associated with thin bands of limestone within 2 or 3

feet of the coal. In several mines the shale adheres closely to the coal, and some falls with it. Beneath the bed occurs a thin layer of fire clay. The coal is easily cut in all directions, there being no strong development of face or butt cleats. In a few mines this bed generates inflammable gas, but it is not dangerous under normal mining conditions.

Analyses of coal No. 5 and of one coke sample from this bed are given in the table on page 135. At Dekoven, Ky., this coal is coked extensively after washing. At Equality the Gallatin Coal and Coke Company converts its slack into coke, which is marketable, although somewhat higher in ash and sulphur than is desired. Experiments are now in progress looking to improvement of the quality. As Illinois produces no coke except from this bed, so far as shown by published reports, thorough experiments with it are very desirable.

COAL NO. 7 (EQUALITY COAL).

Coal No. 7 is mined for shipment at Norris City, and for home use at two small mines near Equality, where the bed outcrops. It is identical with coal No. 11 of Kentucky. The position of the bed is approximately 50 feet below coal No. 8, 55 feet above coal No. 6, and 90 to 128 feet above coal No. 5. It is thought to lie about 275 feet below the Carthage limestone and 550 feet or more above the Caseyville conglomerate.

The average thickness of the bed, as reliably indicated at 61 places in the area, is 4 feet 4 inches. In seven of these localities it is less than 4 feet thick, and in four others is practically absent. Present data indicate that the areas of thin coal are only local, and that there is no definite tendency to thin out in any particular direction. Thus the coal may be well developed within three-fourths of a mile from points where borings show it to be less than 4 feet thick. At Norris City, where the greatest measurements were obtained, the bed ranges from 5 feet 9 inches to 6 feet 6 inches. The coal is lustrous black, and where seen is tender and brittle. The high quality of the coal itself is impaired by a persistent band of clay shale, which ranges from half an inch to 3 inches, and averages about 2 inches in thickness. This occurs from 12 to 24 inches above the fire clay, but usually about 18 inches. From 6 to 10 inches below the top of the coal there is also a rather persistent sulphur streak, which is usually less than one-half inch thick, but may measure 1 inch. A few other patches or streaks of sulphur occur locally through the bed. Analyses of coal No. 7 appear in the accompanying table (p. 135).

The mining conditions of this bed, though not known from extensive operations, are apparently good. A layer of black shale, varying in thickness up to 17 inches, and locally banded, separates the top of the coal from a limestone that is from 4 to 7 feet thick. However, sandstone is said to overlie and partly cut out the coal at places in the

mine at loc. 67. Care is necessary to prevent the shale from falling with the coal. The bed is underlain by 1 to 5 feet of fire clay. Here and there small rolls or horsebacks are present, and the character of the roof and floor is such that squeeze or creep is liable to occur unless care is exercised in mining.

CHEMICAL ANALYSES OF THE COALS.

The accompanying analyses indicate that the coals of this area rank with the very best of the State. The several results, however, are not equally suited for close comparison with other analyses, since some represent samples which were taken and analyzed under unknown conditions, and even though they may have been, when fresh, truly representative of the several mines, they are not known to have been similarly handled, either to preserve the normal moisture content or to expel part or all of it. Higher efficiency, of course, is shown by dried samples, other things being equal, than by those which contain moisture. Varying amounts of time elapsed between taking and analyzing the several samples, and it has been shown by chemists at the State Geological Survey that those which stand long before analysis lose volatile matter when opened, and that the resulting efficiency determinations are really lower than they should be. The analyses here presented were obtained under the conditions described below.

Analyses 1, 14, 17, and 18 were made by W. F. Wheeler, of the Illinois Geological Survey, from samples collected by the writer in the following manner: A clean exposure, representative of the average condition of the bed, was grooved from top to bottom and the sample collected on clean oilcloth. No impurities were thrown out except those usually excluded from commercial shipments. The sample was further prepared in the mine or at the surface by crushing, mixing, quartering, and sealing in an air-tight can as quickly as possible in order to preserve the normal moisture of the coal. Analyses were made after four to five months without air drying the samples.

Analysis 1 represents a sample from the end of the first west entry off the main south entry, about 1,000 feet from the shaft, where the coal measures 4 feet 6 inches. The sample was prepared in the mine without excluding impurities and was immediately sealed on reaching the surface. It is probable that some extraneous water reached the sample while ascending the shaft.

Analysis 14 represents the bed at the end of the first main north entry, 400 feet from the shaft, where it has a thickness of 5 feet 4 inches. A little of the sulphur showing at this place was excluded from the sample. The coal was prepared and sealed promptly above ground.

Analysis 17 represents the coal at the end of the first entry off the main entry, where it measures 4 feet 7 inches, and shows no impurities which are excluded from shipment. This sample was prepared and sealed within five minutes after leaving the mine.

Analysis 18 represents coal taken at the country mine of Mr. Dobbin, where the following section was measured:

Section in Dobbin's mine.

		Ft.	In.
	Limestone	4	
	Shale	1	
1.	Coal		6
2.	Sulphur and shale		½
3.	Coal	2	7
4.	Shale		2½
5.	Coal		10
	Fire clay	4+	
	Total coal bed	4	2

Impurities from layers 2 and 4 are picked from the coal before marketing and are excluded from the sample.

Analyses 8, 13, and 16 were made without air drying by W. F. Wheeler, of the State Geological Survey, from samples collected by F. F. Grout in the manner already described. When analyzed, these samples had stood sealed for eleven months.

Analysis 8 represents a sample taken in the second room off the second west entry, where the coal measures 56 inches thick and shows no persistent bands.

Analysis 13 represents the coal in the first room off the second east entry on the north, where the following section was measured:

Section in O'Gara mine No. 12.

		Inches.
	Shale, pebbly (many feet).	
	Draw slate, second	5
	Draw slate, first	7
1.	Coal	27
2.	Sulphur	⅛ 1
3.	Coal	32
	Fire clay.	
	Total coal bed	60

The sample includes layers 1 and 3. No. 1 has two partings of sulphur 3 inches and 8 inches from the top which are not persistent, but are common in the mine.

Analysis 16 was made from a sample obtained near the shaft, which includes Nos. 1, 3, and 5 of the following measured section:

Section in mine of Norris City Coal Company.

	Ft.	in.
Limestone	4	6
Shale		2-16
1. Coal		7
2. Sulphur		½
3. Coal		31
4. Blue band	up to 3	
5. Coal		18
Fire clay.		

Analyses 2 to 7, inclusive, by Prof. S. W. Parr, of the State University of Illinois, were recently published in Bulletin No. 3 of the State Geological Survey. The samples were collected in canvas bags at the mines from the surface of car lots prepared for shipment, and were sealed in air-tight jars in the laboratory. Since the moisture of the samples after shipment differed presumably by varying amounts from that shown under normal conditions in the mines, analyses were preceded by air drying.

Of analyses 9, 10, 11, and 12, kindly furnished by Superintendent Thomas, of the O'Gara Coal Company, No. 9 was made by Professor Parr and the others by various private chemists. The exact method of sampling and treatment before analysis is not stated.

Analysis 15, made by the General Chemical Company, of Chicago, was obtained through the courtesy of Supt. J. B. Kitch, of the National Mining Company. The percentage noted in the sulphur column includes "sulphur and waste."

Analyses 19 and 20, made by Regis Chauvenet & Bro., of St. Louis, for the Gallatin Coal and Coke Company, were kindly furnished by President Hugh Murray.

Analyses of coal and coke from Saline-Gallatin field, Illinois.

	No. on Pl. VII or VIII.	Mine.	No. of bed.	Size.	How obtained.	Condition.	Moisture.	Ash.	Volatile matter.	Fixed carbon.	Sulphur.	British thermal units.
1	116	O'Gara Coal Co. No. 10 (Eldorado Coal and Coke Co.).	5	.....	Face cut	As mined	8.43	8.85	.....	.....	1.98	12,026
2	116	.....do	5	Lump	Car	Air dry	5.68	8.90	33.32	52.10	1.18	12,668
3	116	.....do	5	Slack	.....do	.....do	4.36	23.58	29.36	42.70	2.00	10,400
4	116	.....do	5	.....do	.....do	.....do	5.04	10.88	34.36	49.72	4.00	12,179
5	116	.....do	5	.....do	.....do	.....do	4.00	20.88	30.78	44.34	3.70	10,924
6	119	O'Gara Coal Co. No. 1 (Diamond Coal Co.).	5	Lump	.....do	.....do	4.10	6.76	37.17	51.97	1.55	12,940
7	119	.....do	5	Slack	.....do	.....do	4.72	14.28	32.72	48.28	2.70	11,351
8	115	O'Gara Coal Co. No. 8	5	.....	Face cut	As mined	6.93	8.12	.....	.....	1.69	12,298
9	115	.....do	5	.....	Not known	Not known	2.31	7.67	34.75	55.27	.53	12,678
10	115	.....do	5	.....	.....do	.....do	4.84	6.26	29.59	57.80	1.51	.....
11	115	.....do	5	.....	.....do	.....do	4.64	6.32	31.24	57.80	1.50	.....
12	115	.....do	5	.....	Face cut	.....do	2.37	11.28	30.07	56.28	2.16	12,840
13	120	O'Gara Coal Co. No. 12 (Harrisburg and Big Muddy Coal Co.).	5	.....	.....do	As mined	5.38	8.47	.....	.....	2.40	12,475
14	96	National Mining Co	5	.....	.....do	.....do	4.69	11.74	.....	.....	4.03	12,211
15	96	.....do	5	.....	Not known	Not known	.....	7.18	38.16	54.66	3.03	13,000
16	28	Norris City Coal Co	7	.....	Face cut	As mined	7.97	10.73	.....	.....	2.68	11,512
17	77	East Side Coal Co	5	.....	.....do	.....do	4.30	10.74	.....	.....	4.36	12,452
18	93	Dobbins bank	7	.....	.....do	.....do	5.73	11.19	.....	.....	3.13	12,177
19	80	Gallatin Coal and Coke Co	5	.....	Not known	Not known	1.91	9.75	34.99	53.35	2.14	.....
20	80	.....do	5	Coke	.....do	.....do	0.00	15.61	1.43	82.96	2.28	.....

DESCRIPTION OF COAL MINES.

The appended table presents a list of the coal mines of this area. Inasmuch as the district includes old and new mines, both primitive and modern methods of mining are employed. This paper does not review in detail the technology of these mining methods, but merely outlines prevalent or important conditions.

In the mines visited,[a] which are laid out according to various adaptations of the room-and-pillar plan, pick mining prevails, and the coal is shot down, then hauled in wooden cars of 1 to 2 tons capacity, by mules. Usually the shafts are divided into two parts, 9 by 14 feet each, and are provided with single-decked cages of metal construction, with safety clutches. The most popular hoisting engine is one that acts directly on a 6-foot drum. The coal dumps automatically into scales and into shaker or revolving screens. Box-car loaders are employed to a small extent. The mines require little pumping, and some need sprinkling in certain seasons. Ventilation is usually effected by Capell propelling fans about 12 feet in diameter. Speaking tubes between engine room and shaft bottom are installed in a few mines, and electric lights are also used underground by the National Mining Company.

Screened coal chiefly is shipped, and although no figures were collected to show the sizes made it is estimated that in some cases as much as 30 per cent is slack. This condition is almost certain to be remedied by the introduction of machine mining. As already stated, at Equality the slack of coal No. 5, after washing, makes a marketable coke, and the further development and perfection of this process is thought to promise much for this field.

Partial list of coal mines in Saline-Gallatin field, Illinois.

Name of mine or owner.	No. on Pl. VII or VIII.	Location.	Character of opening.	No. of bed	Average thickness.		Depth to base of coal.	Remarks.
					Ft.	*in.*	*Feet.*	
Slaten	90	Cottage Grove	Slope	7	4	0	.....	Abandoned.
Dobbin	93	Northwest of Equality	Shaft	7	4	2	57	Local.
East Side Coal Co	77	Equality	do	5	4	7	40	
Gallatin Coal and Coke Co	80	do	do	5	4	10	80	
Gold Nugget	78	do	do	5	4	7	40	
Gordon	67	Northeast of Equality	Slope	7	4	2	41	Local, suspended.
Hargrave	75	East of Equality	Drift	5	4	3	.....	
McLain	61	North of Equality	do	7	4	2	.....	Local.
National Mining Co	96	Southeast of Eldorado	Shaft	5	5	4	336	
Norris City Coal Co	28	Norris City	do	7	5	4	640	
O'Gara Coal Co., No. 1	119	4 miles southwest of Eldorado.	do	5	.....		302	
O'Gara Coal Co., No. 8	115	Eldorado	do	5	4	6	407	
O'Gara Coal Co., No. 10	116	do	do	5	4	6	411	
O'Gara Coal Co., No. 11	117	do	do	5	4	6	404	
O'Gara Coal Co., No. 12	120	5 miles southwest of Eldorado.	do	5	.....		421	
Percil	62	North of Equality	Drift	7	4	2	.....	Abandoned.
Sanks	76	East of Equality	Slope	5	4	4	27	Local.
Swinney	94	Northwest of Equality	Shaft	7	4	2	30	Suspended.
Vandell Mining Co	74	Junction	do	7?	.....		.....	Sinking shaft.
Wasson Coal Co	118	2½ miles southwest of Eldorado.	do	5	.....		328	Do.

[a] The mines at locs. 80, 119, and 120, which lie beyond the borders of the quadrangles proper, were not examined personally in this preliminary work.

THE ARKANSAS COAL FIELD.

By Arthur J. Collier.

INTRODUCTION.

Both the Carboniferous and Tertiary rocks of Arkansas contain extensive deposits of coal, but only those of the older system have been exploited and are known to the trade. They grade from bituminous to semianthracite, and recent experiments at the United States Geological Survey fuel-testing plant have demonstrated that they are of a quality not to be found elsewhere in the United States west of West Virginia.[a] Mining operations within the field have demonstrated that its structure is more complex and the areas of workable coal more limited than the results of previous surveys would indicate.[b] For these reasons a detailed reconnaissance of the field was made from March 1 to August 1, 1906, the results of which are embodied in Bulletin No. 326 of the United States Geological Survey, soon to be issued, from which the following paper is abstracted.

GEOGRAPHY.

The coal field herein described is situated in the western part of Arkansas, adjoining the Indian Territory line, from which it extends eastward along the Arkansas River valley for 75 miles. (See Pl. IX.) It is about 50 miles wide at its west end, but the belt containing workable coal contracts abruptly 12 miles from the boundary, and beyond this point the average width is not more than 20 miles. The workable coal areas are more or less irregularly distributed over this district, and many of them are in detached basins not known to be connected with one another. The productive areas of the east end of the field are north of Arkansas River; those of the west end are south of it.

[a] Campbell, M. R., Classification of coals, in Report on the operations of the coal-testing plant: Prof. Paper U. S. Geol. Survey No. 48, 1906, pp. 156-173.

[b] The Geological Survey of Arkansas, under the direction of Dr. J. C. Branner, made a comprehensive investigation of this coal field and in 1888 published a preliminary report entitled "Geology of the coal regions," by Arthur Winslow. (See Ann. Rept. Geol. Survey Arkansas, 1888, vol. 3.) Mr. Winslow's final report has, unfortunately, never been published. The topographic maps made to accompany this report were prepared jointly by the State and Federal surveys, and they have been used in the present investigation.

Fort Smith, the center of the coal-mining industry, is the principal town in western Arkansas and has a population of about 20,000.[a] It is approximately 250 miles from Kansas City, 350 miles from St. Louis, and 400 miles from the Gulf of Mexico, with which points it is connected by railroads. Branch lines and independent railroads of less importance radiate from Fort Smith and afford transportation to the various local mining centers.

GENERAL GEOLOGY.

The Arkansas field comprises the east end of a large area of coal land which has its greatest extent in Indian Territory, where the stratigraphic relations have already been studied in detail and mapped by the geologists of this Survey. A part of the northern edge of the coal field in Arkansas has also been mapped and the results of these investigations published or submitted for publication.[b] The formations comprising the stratigraphic column in Arkansas are directly comparable to those of Indian Territory and there is also a marked similarity in the general type of geologic structure in the two districts. The various rock formations as defined and named in Indian Territory are therefore practically identical with those which are present in the Arkansas coal field.

STRUCTURE.

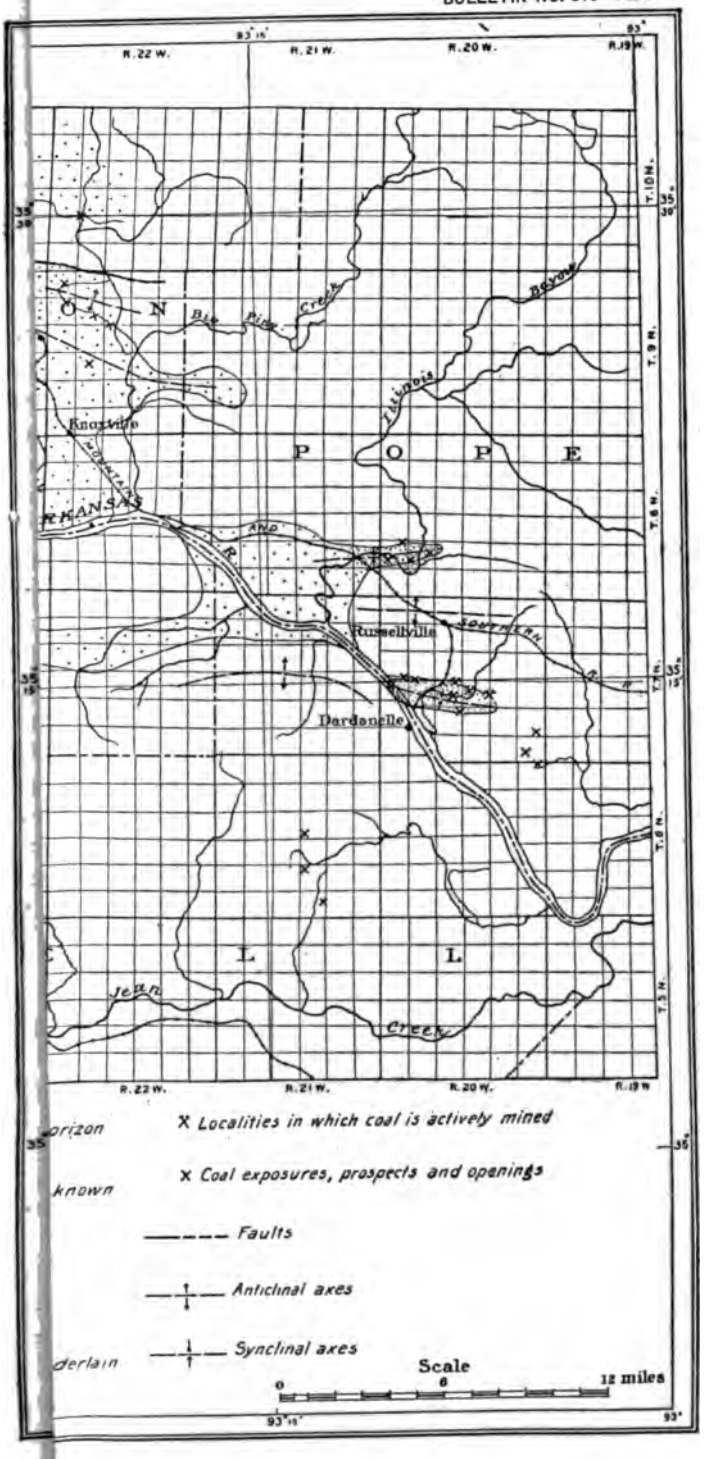
GENERAL CONDITIONS.

The coal field lies in a long, comparatively narrow synclinal trough extending eastward along the Arkansas River valley from the Indian Territory line. North and south of the field the coal-bearing strata have been eroded, leaving only barren rocks exposed. This trough lies between the Boston Mountains on the north and the Ouachita Mountains on the south. These ranges, as will be shown, are very diverse in their geologic structure.

The various strata comprising the Ouachita Mountain mass have been compressed in a north-south direction, being thrown into folds whose axes extend approximately east and west. Subsequent to this crumpling the upper parts of the folds have been eroded, leaving the edges of the harder beds projecting in ridges as we now find them. In the process of folding the strata were often broken and in many localities the beds slipped out of place, so that their outcrops are not

[a] The population of Fort Smith in 1900, as determined by the Eleventh Census, was 11,587.

[b] Taff, J. A., and Adams, G. I., Geology of the eastern Choctaw coal field: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 259-311. Taff, J. A., Geologic Atlas U. S., Coalgate folio (No. 74), 1901; Atoka folio (No. 79), 1902; Tahlequah folio (No. 122), 1905. Sallisaw and Windingstair folios, in preparation; The southwestern coal field: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, pp. 361-413; Maps of segregated coal lands in Indiana Territory: U. S. Dept. Interior Circulars Nos. 1, 2, 3, 4, 5, 6, 1904. Purdue, A. H., Geologic Atlas U. S., Winslow folio, in preparation.


R. 22 W.
R. 21 W.
R. 20 W.
R. 19 W.
T. 10 N.
T. 9 N.
T. 8 N.
T. 7 N.
T. 6 N.
T. 5 N.
35° 30'
35° 15'
93° 15'
93°
O N
P O P E
L L
Big Piney Creek
Illinois Bayou
Knoxville
Russellville
Dardanelle
Jean Creek
ARKANSAS AND SOUTHERN
X Localities in which coal is actively mined
X Coal exposures, prospects and openings
Faults
Anticlinal axes
Synclinal axes
Scale
0
6
12 miles

now continuous for very great distances. In general these fractures are of the type called thrust faults, and the rocks on the south side have ridden over those on the north. The faults extend approximately east and west, parallel with the trend of the ridges.

The rocks of the Boston Mountain province are not folded like those of the Ouachita province, but, on the other hand, are in most places only slightly distorted from their original positions, and are characterized by low dips. This part of the earth's crust appears to have been raised up into a broad, flat dome. Where such a movement has occurred the beds at the two levels must either bend or break, and both kinds of adjustment are to be seen along the southern margin of this mountain province. The flexures are of the type described as monoclines or monoclinal folds, and the fractures or faults are of the normal type, differing from those in the Ouachita Mountains in that they occur in beds not crumpled by lateral pressure and otherwise little disturbed from their original positions. Normal faults of this type are characteristic of the geologic structure of the Boston Mountains, and a series of them extends approximately east and west along the north side of the Arkansas Valley, separating the Boston Mountain province from the coal field. It will be seen from this description that the Arkansas Valley syncline, which contains the coal field, is peculiar in that on the south side the underlying rocks rise up by pronounced folds and thrust faults, whereas on the north side they are brought to the surface by a simple monoclinal uplift, accompanied at many places by normal faulting. The structure within the coal field partakes of the nature of both these types.

ANTICLINES.

Although the field in general may be described as a synclinal trough, in its detail it is folded into a number of minor interlocking synclines and anticlines, which have east-west axes only a few miles in length. The position and extent of these axes are shown on the map (Pl. IX).

One of the best-known anticlines in the whole district is that in Backbone Ridge, between Bonanza and Hackett, which extends from the State line eastward for 7 or 8 miles. The coal-bearing beds which outcrop on both sides of this ridge are steeply tilted and in its axis rocks lying far below the coal horizon are exposed. This anticline is an unsymmetrical fold of the Ouachita Mountain type and represents a thrusting of the rocks from the south over those on the north side of the axis. The strata are broken, and a well-marked thrust fault has been traced along the axis for several miles.

A somewhat similar fold with overthrust of the rocks from the south is indicated by Devils Backbone and Pine ridges, which mark

the southern boundary of the coal field in the region east of Greenwood.

The Prairie View anticline, in the eastern part of the field, is another important fold, as it brings up the rocks below the coal horizon and forms a barren area. This fold is probably also of the Ouachita type, inasmuch as there is a fault with downthrow to the north along its northern limb.

Most of the other anticlines indicated on the map are more moderate flexures not accompanied by faults, although those of the southern part of the field are usually unsymmetrical, the steeper dips being on the north.

The Massard Prairie anticline, a broad open fold southeast of Fort Smith, and the Hartford or Coops Prairie anticline, south of Mansfield, have been successfully exploited for natural gas.

SYNCLINES.

The synclines are as a rule broad, open folds which carry the principal coal horizon only to moderate depths. Generally those of the southern part of the field are unsymmetrical, the dips on the south side being steeper than those on the north. Their axes are marked in many places by high hills or buttes formed by the erosion of flat-lying beds. Poteau, Sugarloaf, Short, and Magazine mountains are of this character, and below them the principal coal horizon attains its maximum depth from the surface in the Arkansas field. Many of the shallower synclines contain extensive areas of coal that are workable under present conditions. These are further described in connection with the coal beds (pp. 142–157).

FAULTS.

The faults indicated on the map (Pl. IX) include both normal and thrust types. Eleven faults of large proportions and a number of smaller unimportant ones are known within the coal field, and it is probable that there are others which were not recognized in this somewhat rapid reconnaissance. Most of these are mapped here for the first time and were not discovered by previous surveys. The recognition of features of this kind in a region like the Arkansas coal field, where all the rocks are so similar to each other, is very difficult, and it has been practically impossible to locate them at all points with the accuracy desired. Their positions as shown on the map must therefore be regarded as only approximate.

The best-known fault in the district is that along the axis of Backbone Ridge. This displacement was recognized by the geologists of the Arkansas Survey and is represented on the geologic map published in the preliminary report on the coal field. Its west end in

Indian Territory has also been located. It extends from the boundary eastward for about 8 miles to a point a mile northwest of Greenwood. Measurements made during the last field season indicate that the displacement is nearly 5,000 feet at the State line. This fault is of the thrust type. It occurs in barren rocks and does not affect the economic value of the field. Faults of similar character probably also occur in some places along the southern boundary of the coal field in what is known as Devils Backbone Ridge at Chismville and Pine Ridge farther east.

The Prairie View fault, which extends from sec. 25, T. 8 N., R. 25 W., eastward for about 7 miles to Arkansas River, is probably also of the thrust type, since it is associated with a rather pronounced fold and the downthrow is to the north. The displacement is not less than 500 feet. This fault defines the southern limit of what is called the Prairie View coal field.

The faults which occur along the northern edge of the coal field are of the normal type, with the downthrow usually to the south. They are much more difficult to discover than those described, since the evidence for them is obscure, and they are very troublesome to the geologist who attempts to interpret the structure of the coal field. At their extremities the displacement gradually grows less and disappears so that the beds can be traced continuously around the ends. By many of the faults, however, sandstone beds are brought against other sandstones and shales against shales, so that it is only by the most careful study that the displacement can be recognized or its nature determined. The displacement by these faults is comparatively small, the maximum amount known being only 500 feet.

STRATIGRAPHY.

All the rocks of the coal field belong to the upper Carboniferous, or Pennsylvanian series. They present a rather monotonous sequence of sandstones and shales, with little contrast between individual beds. Except the coal beds themselves there are no members that can be identified with certainty by lithologic characters. Limestones, which in many other fields aid the geologist by serving as horizon markers, are here almost totally wanting. Fossil plants and invertebrate animals are fairly abundant at certain horizons, but there was very little change in plant and animal life during the period when these rocks were deposited, and such fossils are therefore of little use in stratigraphic correlations. There is also much variation locally in the rocks, especially in the sandstone lenses, and correlations from one part of the field to another based on lithologic similarity are of little value.

The coal-bearing rocks in Indian Territory comprise several thousand feet of sandstones and shales, which have been divided as follows:

Coal-bearing formations of Indian Territory.

	Feet.
Boggy shale	2,000
Savanna sandstone	1,000
McAlester shale	2,000
Hartshorne sandstone	200

The coal-bearing rocks of Arkansas are less than 2,000 feet thick and are equivalent to the McAlester shale of Indian Territory. The Hartshorne sandstone at the base of the section is a thin but very persistent formation, which has been traced for 150 miles along the southern edge of the Indian Territory field, but has not heretofore been identified at its northern edge. In Arkansas this sandstone member has been traced eastward from the State line for 75 miles to the eastern extremity of the coal field and has also been identified along the northern edge of the field. Although it is thin and somewhat variable, it is rather more distinctive than most of the members of this series and may be regarded as the most definitely marked formation to be found in the region. The coal-bearing rocks of Arkansas are as follows:

Coal-bearing formations of Arkansas.

	Feet.
McAlester group:	
Paris shale—sandy shale containing some thin beds of sandstone and including the Paris coal bed	700
Fort Smith formation—shaly sandstone and sandy shale, including the Charleston, Central, and Philpott coals	400
Spadra shale[a]—shale including some lenses of sandstone and sandy shale, and overlying the Hartshorne coal	500
Hartshorne sandstone	100–300

COAL BEDS.

Coal beds large enough to be worked occur in the coal-bearing rocks in three stratigraphic positions, which will be described as the Hartshorne, Charleston, and Paris horizons. The most important coal beds occur at the base of the Spadra shale, immediately above the Hartshorne sandstone, in a stratigraphic position which is conveniently described as the Hartshorne horizon. The second coal-bearing horizon, which is of minor importance, is stratigraphically from 800 to 900 feet above the Hartshorne coal and will be called the Charleston horizon, since the coal is best known in the vicinity of that town. A third horizon is that of the coal bed mined at Paris, which probably corresponds approximately to the McAlester coal of Indian Territory.

[a] The name Spadra stage applied to this formation was published in 1896 by John J. Stevenson, who credited it to geologists of the Arkansas Survey. See Trans. New York Acad. Sci., vol. 15, 1896, p. 51.

This coal is from 1,200 to 1,400 feet above the Hartshorne horizon. Nearly all the various coals that have been mined in Arkansas can be correlated with one or another of these horizons, though some small lenses of coal, which have been mined for neighborhood use, occur locally at many places in rocks that lie below the Hartshorne sandstone, and it is quite possible that future development will establish the fact that there are small areas of valuable coal at other horizons than those noted.

COALS OF THE HARTSHORNE HORIZON.

The coal beds that occur at or near the horizon of the Hartshorne coal are economically the most important both in Indian Territory and in Arkansas. This horizon is at the contact of the Hartshorne sandstone with the shale which overlies it, and in general the coal is taken as the line of demarcation between these formations. There is, however, usually from a few inches to 20 or 30 feet of shale or fire clay between the coal bed and the hard sandstone, a condition due to local variations either in the character of the upper part of the sandstone member or in the exact position of the coal itself. The shale in its lower part is apt to be sandy, and in some places contains lenses of hard sandstone which lie immediately above the coal bed and make it difficult to determine the contact of the Hartshorne and Spadra formations. The coal bed is subject to great local variation in thickness and character. Partings come and go without reference to any known rule, and in some places the coal is wanting. These local conditions and variations are best described under the headings of the various districts in which it is mined.

BONANZA AND JENNY LIND DISTRICT.

The Bonanza and Jenny Lind district lies north of Backbone Ridge in Sebastian County and includes several important mines which are located along the southern outcrop of the coal bed near the towns which give the district its name. The position of the outcrop is indicated by the Hartshorne sandstone, which is easily traced along the north side of Backbone Ridge and Biswell Hill to Oak Valley, where it turns southward and connects with the sandstone that underlies the coal at Greenwood and Hackett. From its southern outcrop at Jenny Lind the coal dips to the north at a low angle for about 4 miles, reaching a depth of 600 to 900 feet below the surface. It then rises with a still more gentle slope and outcrops at several points on Massard Prairie, beyond which it dips northward again and passes under Fort Smith. In this district the areas in which the coal is near the surface are indicated by the extent of Long and Massard prairies.

In the basin north of Jenny Lind the greatest depth to coal probably does not exceed 850 feet, while in a large part of the district it is within

500 feet of the surface. At Central, a small town 6 miles northeast of Jenny Lind, coal has been mined from a smaller bed estimated to be about 850 feet above the Hartshorne coal; this bed is described in connection with the Charleston horizon (p. 154). The nature of the Hartshorne coal bed is best known in this district along the outcrop between Bonanza and Jenny Lind, where it has been mined for 2½ miles northward from the outcrop. It is thick enough for mining along this outcrop line for 10 miles, nearly all the way from Bonanza to Oak Valley, beyond which point it is reported to be too thin for mining. In general the bed consists of two benches of coal with a variable shale parting near the center. It is thickest in a mine near Jenny Lind, where it measures over 6 feet in some places, but thins gradually east and west from this point, being less than 4 feet thick at the State line, 5 miles to the west, and not more than 3 feet thick at an exposure 4 miles northeast of Jenny Lind.

The coal in all these mines has a luster which is somewhat brighter in the upper bench than in the lower. It is not very definitely jointed and the cleat is not considered in mining. In some places a definite system of joints which do not affect the coal is apparent in the harder parts of the roof. The roof and floor generally consist of hard, more or less sandy shale; usually the floor is a little harder than the roof. Neither roof nor floor has any features that are unfavorable to mining, though in one of the mines (No. 18, near Jenny Lind) parts of the roof are apt to fall on account of the jointing.

The only knowledge which we have of the coal for a distance of several miles beyond the northern limit of present mining development is that obtained by drilling. Over a comparatively large area believed to be coal land drill holes have been put down to the coal at intervals rather too great to fully demonstrate the value of the land. About 6 miles north of the Jenny Lind outcrop, however, on Massard Prairie, this coal bed shows again, its outcrops surrounding a barren area in the center of the prairie. Coal has been mined here from strip pits almost continuously for a distance of 3 miles. The bed ranges in thickness from 14 to 30 inches and is divided by a thin parting of shale a little below the middle. In general, the coal of the upper bench is softer and of better quality than that of the lower.

GREENWOOD AND HUNTINGTON DISTRICT.

The Hartshorne coal bed is continuous over an extensive region south of Backbone Ridge, in Sebastian County, where a large number of more or less important mines are located along its outcrop. Although the same bed is believed to extend over this whole region, the character of the coal and peculiarities of the bed vary so much locally as to make a number of minor divisions necessary in describing

it. In general, the whole region could be divided by a line running south-southwestward from Greenwood into a western part in which the coal bed is without partings and free from excessive ash, and an eastern part in which the coal bed is thicker but divided and relatively impure.

From Hackett, near the Indian Territory line, the coal outcrop south of Backbone Ridge has been traced eastward to a point several miles beyond Greenwood, where it turns to the north and connects with the outcrop of the Bonanza and Jenny Lind coal bed. From this line of outcrop the bed dips southward into the Greenwood syncline, south of which it rises and outcrops along the flank of Devils Backbone Ridge. This ridge, which extends far to the east in a nearly straight line and marks the southern boundary of the coal field, turns abruptly to the south a few miles southwest of Greenwood and carries the coal outcrop to the heart of a minor anticline between Midland and Montreal, in sec. 13, T. 5 N., R. 32 W. The outcrop line then turns eastward, with the coal dipping to the south, and extends for several miles, to Huntington. This town is situated in a syncline around the end of which the outcrop turns westward, with the coal dipping to the north, and extends in a nearly straight line to Hartford, where it again turns to the east, swinging around the Hartford anticline. The outcrop east of Hartford was followed for only 10 miles, the investigation being then given up because the coal bed, although still of considerable size, was found to be so divided by partings as to make it of questionable value.

From the above description it will be seen that the Greenwood and Huntington district covers a large and roughly rectangular area, including several townships of land on which the almost continuous line of outcrop indicates that the coal bed exists in sufficient size to make it of economic value. In a part of the district, notably that immediately east of the towns of Montreal and Midland, there is an upper coal bed from 40 to 60 feet above the Hartshorne coal, which probably corresponds with the upper Hartshorne coal reported from many points in Indian Territory. Where reported in Arkansas the upper Hartshorne coal is invariably an impure, dirty bed broken by many shale partings and is probably nowhere of economic value. The lower coal bed ranges in thickness from a minimum of 2 feet to a maximum of not less than 8 feet. Its floor is usually only a short distance above the harder beds of the Hartshorne sandstone, but its roof has been found to be variable. Although the roof generally consists of shale, a heavy lens of hard, in many places cross-bedded sandstone, having a maximum thickness of 60 feet, overlies the coal bed for several miles at Montreal and Burma. In the northwestern part of the district the bed is without partings and is from 2 to 3½ feet thick. In the southeastern part it increases in size locally to 6 or 7

feet and is divided by one or more partings of shale. As a general rule, chemical analyses show that the coal is of better quality in the western than in the eastern part of the district.

The coal bed has been opened in a number of mines, small slopes, and strip pits along the whole line of outcrop described and some of the workings have extended back for as much as 1½ miles. Beyond these workings, however, the only source of information as to the character of the coal consists of a few scattered drill holes. Although it can not be said that the whole district has been prospected sufficiently to prove that it is all underlain by valuable deposits of coal, yet the evidence at hand seems to indicate that there is little doubt that the greater part is valuable coal land. The coal lies at its maximum depth of 1,400 to 2,500 feet below the surface beneath Sugarloaf and Poteau mountains. On the lower lands surrounding the Sugarloaf Mountain it is not probable that the depth of the coal is more than 900 feet at any point, and the average depth to coal probably does not exceed 600 feet. The details in the following paragraphs are given in the order of the various mines and openings at which the coal has been examined along the lines of outcrop.

Along the outcrop line south of Backbone Ridge, from Hackett to Excelsior, the coal bed is without partings and is from 2½ to 3½ feet thick. Analyses show that it is freer from ash and probably has a higher calorific value than any of the other coals sampled.

For several miles east of Excelsior the bed is thicker, but is divided and contains a higher percentage of ash. At Greenwood the bed measures 7 feet, with a shale parting which ranges from a fraction of an inch to 6 inches in thickness. Two miles farther east, at the Fidelity mine, the thickness is nearly 8 feet, but the bed contains much bony and shaly matter, and only about 4 feet of coal in one bench is available for mining. East of Fidelity the bed thins rapidly and is not mined.

On the outcrop line which follows Devils Backbone Ridge southeast of Greenwood, small exposures have been found at points several miles east of the town, but no coal has been produced nor have the beds been opened sufficiently to permit accurate measurements. The inclosing rocks are steeply tilted and in places slightly overturned and sheared so that the coal is probably more or less crushed. Small amounts of coal have been obtained from a strip pit in sec. 18, T. 6 N., R. 30 W., at a point where Vache Grasse Creek cuts across Devils Backbone Ridge; but the workings have all been abandoned and it was impossible to learn the thickness of the coal or the detail of its section.

Along the outcrop line running southwestward from Greenwood to Montreal and Midland the coal bed, so far as known, is without partings, and in quality resembles that at Hackett. In general, the

exposures show from 2 to 4 feet of coal. The dips range from 1° to 15°, but it seems to be invariably true that where the dip is high at the outcrop it rapidly decreases and the coal bed flattens in depth. The bed changes in character east of Burma, becoming very much thicker and divided by several partings.

An upper bed corresponding to the upper Hartshorne coal of Indian Territory is indicated by drill records in the vicinity of Midland and Burma. This bed, which is 60 feet above the lower one, has a maximum thickness of approximately 5 feet, but is generally shaly or bony, and is described as a "dirty vein."

The coal bed in the Huntington basin is thicker than at Midland and Burma, but it is divided by shale partings, and chemical analyses show that it contains a rather high percentage of ash in the merchantable coal. This character of the bed prevails along the outcrop to the southwest nearly to Hartford, where the bed is not divided. East of Hartford, on the outcrop which lies south of the Hartford anticline, the bed is so divided by partings as to be of little value.

There are two large mines operated from shafts as well as several strip pits in the synclinal basin near Huntington. The coal bed, which is between 7 and 8 feet thick, is in three benches, separated by thin shale partings.

In sec. 32, T. 5 N., R. 31 W., the bed is 8 feet thick, with a parting of several inches of shale near the center, and is known as the "Mammoth vein." It is without partings, and measures 3½ feet at the town of Hartford, in sec. 10, T. 4 N., R. 32 W., where it is worked from a number of small slopes and two larger ones. Southeast of Hartford, in secs. 13 and 14, T. 4 N., R. 32 W., the bed again resembles that at Huntington and Greenwood in that it consists of several benches of coal with partings between. There are no active mines east of this point, but the coal has been prospected and it is common report that the bed is separated into many benches. At the Chasteen slope, in sec. 18, T. 4 N., R. 31 W., the bed is upward of 8 feet in total thickness, but it is very much divided and contains no bench of coal thicker than 2½ feet. No measurements were made east of this point, though the outcrop of the coal has been traced for several miles.

BATES AND COALDALE DISTRICT.

The coal bed which dips to the south from Hartford and passes under Poteau and Whiteoak mountains comes to the surface again in a line of outcrop parallel with the south flank of Poteau Mountain, where it has been traced from the Indian Territory line eastward for a distance of about 20 miles.

At the State line the bed consists of more than 7 feet of coal divided by two partings of shale. Three miles east of the State line, in sec. 21, T. 3 N., R. 32 W., the coal bed is divided into three benches and

contains an aggregate of 8 feet of coal, the largest bench being 4 feet thick, and the two smaller upper ones not being mined. Nine miles farther east the coal bed still has a thickness of 4 or 5 feet, but is divided into many small benches, the largest of which is only 12 inches thick, and it is not probable that the coal can be successfully mined, though it is possible that part of the bed was not exposed. Croppings of this bed have been observed for 2 miles still farther east, but as it has nowhere been opened no section could be measured, nor have any reports indicating a workable coal bed been received.

The portion of the coal field which extends eastward from Lookout Gap and underlies Whiteoak Mountain was not examined, owing to the short time available for field work. Although the Hartshorne horizon is known to extend over a considerable area here, prospectors' reports indicate that the coal bed is divided and may be of little value. Both north and south of Poteau Mountain the rocks dip at high angles, indicating that the coal is very deep in the center of the syncline. It is probable, however, that all of the coal can be mined from slopes entering the basin from the north and south sides.

CHARLESTON AND PARIS DISTRICT.

The coal of the Hartshorne horizon has not been opened nor the thickness of the bed measured east of Auburn for a distance of about 35 miles to what will be described as the Prairie View district. This unexplored region includes the towns of Charleston and Paris, near which coals of higher horizons are mined. The Hartshorne coal should outcrop through the whole length of this region along the northern base of Devils Backbone Ridge and its eastern extension, Pine Ridge. It should also outcrop near the southern base of Mill Creek Ridge on Grand Prairie, which extends from Arkansas River at the mouth of Big Creek eastward to Roseville.

Along the southern outcrop line, on Devils Backbone and Pine ridges, the bed is here and there indicated by coal smut, but it is nowhere exposed and its thickness can not be measured. There are some indications of a fault along the northern outcrop, on Grand Prairie, and it is possible that the coal horizon does not reach the surface, though it can not be at a very great depth. Coal, which is probably in the Hartshorne horizon, is reported in several wells near Vesta, but no definite information regarding it was obtained, as no accurate measurements had been made.

The Prairie View coal bed, described in some detail on page 151, undoubtedly extends westward in depth under the Paris basin, and though the prospecting which has been done indicates that it thins out in that direction, its western limit has not been determined. The coal bed also dips southward from Denning and must pass under part of this area.

From the above facts it will be seen that there is here a large area underlain by rocks of the Hartshorne coal horizon, in which the thickness and value of the coal have never been determined. The outcrops along the north and south sides of this area reveal no coal of commercial importance, but, considering the great local variations that are known to occur in the Hartshorne coal, further prospecting by deep drilling is fully warranted.

VAN BUREN AND ALMA DISTRICT.

The region in the vicinity of Van Buren and Alma, north of the river, has not been thoroughly prospected, though it also is underlain by rocks of the Hartshorne coal horizon.

A small coal bed very close to if not identical with the Hartshorne outcrops at several places near Mulberry. West of Mulberry this horizon is at a greater depth, and does not outcrop, since at the northern edge of the field it is cut off by a fault north of which sandstones below the coal-bearing rocks are exposed. The depth of the Hartshorne horizon could not be estimated closely on account of the very obscure stratigraphic evidence, much of the surface being covered with deposits of gravel and sand.

Small coal beds found near Alma and Van Buren are provisionally correlated with the Charleston coal, which is about 800 feet above the Hartshorne horizon. What is probably the Hartshorne bed has been reached in a drill hole near Alma at a depth of 700 feet. It is reported to be 9 inches thick and overlies a sandstone 150 feet thick, provisionally correlated with the Hartshorne sandstone.

COAL HILL AND DENNING DISTRICT.

The Coal Hill and Denning district lies north of Arkansas River about 40 miles from the Indian Territory line. Along its north side. the coal is cut off by a fault, extending from Denning to a point a few miles east of Coal Hill, north of which the underlying rocks are raised to the surface. Half a mile south of the line of this fault an anticline extends east and west through the district. In the center of this fold the underlying barren rocks are exposed, but near Denning it pitches below the surface and the coal bed is continuous across it. There is also a smaller basin of coal land, having a possible area of 1 square mile, resting upon the Hartshorne sandstone a few miles west of Altus.

Coal has been mined almost continuously from Coal Hill to Denning and for several miles southeastward from Denning along the southern limb of the anticline. The coal ranges in thickness from 1 to 5 feet, and the bed is usually characterized by a parting of shale or clay near the center, which varies greatly within very short distances, being so thick in some parts of the field as to render the

bed of no value. In general this parting increases in thickness in a northerly direction. South of Hartman the coal bed probably extends eastward and is identical with that mined at Spadra, but for several miles there has been no prospecting sufficient to determine its quality and it does not outcrop at the surface.

In the small outlying basin west of Altus there are two coal beds, the lower one averaging 2 feet and the upper one 10 inches in thickness, with 18 feet of sandy shale between them; these are regarded as equivalent to the two benches of the Denning coal bed. The coal resembles the Denning coal, though, being under only slight cover, it is affected by weathering and the joints are iron stained.

A similar bed with a thick parting of more than 12 feet is indicated by outcrops of coal smut on the south side of the river 2 miles west of this basin, in section 23 of the same township. No coal has been mined here. The outcrop indicates a small shallow basin of coal of the Hartshorne horizon resting upon the Hartshorne sandstone.

SPADRA DISTRICT.

The Spadra district is also north of Arkansas River and its center is about 10 miles east of Coal Hill. The coal differs slightly from that at Denning in that it is considerably harder and of higher grade chemically. It is sold as semianthracite or Arkansas anthracite coal, being mined almost exclusively for domestic use.

The structure of this field is complicated and its interpretation is rendered very difficult by extensive deposits of sand and gravel which conceal a large part of the surface. Available information, however, is sufficient to show that the continuity of the coal bed is broken by several faults of normal type striking approximately east and west and generally with downthrows to the south. The best known of these faults was first encountered in a mine 2 miles northwest of the Spadra post-office. It extends west-northwestward nearly to the town of Hartman, where it turns a little south of west and continues to the center of the Coal Hill field.

Another fault striking nearly east and west marks approximately the southern limit of present mining operations. It is parallel with and a short distance north of Spadra Hill, a long ridge capped by flat-lying sandstones south of Spadra, and its east end is a few hundred yards north of the railroad at the south base of Big Danger Hill, in sec. 23, T. 9 N., R. 23 W., where its position is indicated by conclusive stratigraphic evidence. The displacement at the mouth of Spadra Creek is at least 200 feet. A small fault which differs from those described in that the downthrow is to the north lies north of the western part of the Spadra field, bringing in a small area of Spadra coal at the old Allen slope, in sec. 18, T. 9 N., R. 24 W.

From Spadra the coal bed extends northward for 3 or 4 miles. It underlies the town of Clarksville at a depth of 400 to 500 feet, but outcrops 1½ miles northwest of Clarksville at a point noted by the Arkansas Geological Survey as the Harkreader well,[a] from which the outcrop can not be traced eastward with certainty. The Spadra bed has been penetrated by drill holes west of Cabin Creek at a depth of 550 feet, and the same bed probably outcrops in secs. 6 and 7, T. 9 N., R. 23 W., 2 miles north of Cabin Creek.

At the western limit of prospecting in this district the coal bed is 400 feet below the surface, and its depth probably increases farther west.

Coal mines are located along the railroad for a distance of 6 or 7 miles east from Montana post-office, at very short intervals. Nearly all the openings are by shafts reaching the coal at a depth of 200 feet or less. The average thickness of the coal is from 2½ to 3½ feet, with a small parting near the center of the bed. In general, the coal dips to the north or northwest at a low angle, usually not more than 2 or 3 per cent.

The underground workings of the mines extend for a maximum distance of 1 mile north from the line of the St. Louis, Iron Mountain and Southern Railway. Records of much of the drilling that has been done north of these mines were not available, but it is common report that the parting increases in thickness toward the north and makes some of the coal unfit for mining. A shaft about 1½ miles northwest of Clarksville, near the old Harkreader well, was sunk in 1906, but had not reached the coal at the time of the writer's examination. The coal bed outcrops a short distance to the southeast, however, showing a thickness of 18 to 24 inches without parting.

PRAIRIE VIEW DISTRICT.

The Prairie View district lies on the south side of Arkansas River, opposite the Spadra district. Attempts to prospect the field and determine the extent of the coal land have been made only within the last few years, during which large areas of land in this district have been purchased or placed under option by the Arkansas Anthracite Company.

In structure this field is a broad syncline having a general east-west axis. Its southern edge is marked by the Prairie View fault and its northern edge, which is contiguous to the southern edge of the Spadra field, by the Big Danger fault, both of which are described elsewhere in this paper. The greatest depth to coal found in the basin is 1,100 feet.

Prospect holes in the northern part of the field indicate that the coal is from 3 to 5½ feet thick and divided by a shale parting near the

[a] Ann. Rept. Arkansas Geol. Survey, 1888, vol. 3, p. 24.

center. In the southern part the bed is not divided and is from 1 to 3½ feet thick.

This district is undeveloped and no coal has been mined except for local use. It is not accessible at present from any of the existing railroads, but could be reached by an extension of the Arkansas Central Railroad, which now terminates at Paris. The distance is not more than 15 miles.

RUSSELLVILLE DISTRICT.

The Russellville district lies at the extreme east end of the Arkansas coal field as at present recognized, and includes two small areas of coal land, known as the Ouita basin, a few miles north of Russellville, and the Shinn basin, a few miles to the south.

The coal lands in the Ouita basin are estimated to have covered an area of approximately 2 square miles. Although the formation that carries the coal extends westward, coal has not been mined except in the small area noted, and prospecting a few miles farther west, near London, has revealed no coal. The northern, eastern, and southern boundaries of the Ouita basin are determined by the outcrops of the Hartshorne sandstone, which dips under the coal land from all these directions. The depth to coal is not great at any point, and it has been mined from many small slopes, strip pits, and shafts which have been abandoned and have caved in. Probably much of the coal has been left in the ground and will be lost. Moreover, Illinois Creek, a strong stream which heads in the Ozark Mountains, flows across the basin and has no doubt eroded a great deal of the coal bed, so that much of the area included in the basin as mapped does not contain available coal. Owing to the strike, it was impossible to make measurements of the thickness of this coal bed, but reports indicate that it is without parting and has an average thickness of 28 inches. The roof and floor are shale. As reported by the Arkansas Geological Survey, the coal has a thickness of 26 inches, overlain by 4 inches of bony or "wild" coal.[a]

The Shinn basin lies about 2 miles south of Russellville and includes approximately 2 square miles of coal land. Like the Ouita basin, this is bounded on all sides by outcrops of the Hartshorne sandstone. Shafts which have been sunk for mining purposes show that the maximum depth to coal probably exceeds 600 feet. Coal has been mined for many years along the north edge of the basin, where there are a number of old abandoned slopes, but owing to the great depth of the basin only a comparatively small part of the area has been worked out. The coal is somewhat thicker than in the Ouita basin; it averages between 40 and 46 inches, and has an 8 to

[a] Ann. Rept. Arkansas Geol. Survey, 1888, vol. 3, p. 34.

10 inch parting. There are three active mines in the basin, one of which has a shaft 480 feet deep, making it the deepest coal mine in Arkansas.

PHILPOTT DISTRICT.

The Philpott district lies in an isolated synclinal trough extending east and west through T. 10 N., Rs. 24, 25, and 26 W., north of the Coal Hill and Spadra fields. It includes a number of prospects and small mines which were operated before the larger mines along the railroad were opened. The coal is softer than that at Spadra and for local use formerly commanded a better price, since it ignites and burns more freely. Analyses show that it is semibituminous and of about the same grade as that at Coal Hill and Denning.

There are two beds of coal separated by 600 to 800 feet of shale. The lower of these, known as the Pickartz bed, from the old Pickartz mine, is correlated on stratigraphic evidence with the Hartshorne coal. This mine is situated in sec. 29, T. 10 N., R. 25 W., and the horizon of the coal has been traced to the eastward for a distance of nearly 18 miles, connecting it with the coal which outcrops on Dicks Branch in sec. 10, T. 10 N., R. 23 W., and Minnow Creek in sec. 20, T. 10 N., R. 22 W.

At the Pickartz mine the coal is reported to be from 21 to 26 inches thick, with a thin shale parting near the floor. The coal exposed at Dicks Branch measures 15 inches and at Minnow Creek 14 inches. The upper bed on which the old Moomaw and Philpott mines were located is described in the next section in connection with the coals of the Charleston horizon.

COALS OF THE CHARLESTON HORIZON.

The coals of the Charleston horizon are stratigraphically from 800 to 900 feet above the Hartshorne coal horizon and occur near the upper part of the group of sandstones and sandy shales that constitute the Fort Smith formation. Wherever examined these coals are less than 3 feet thick and are usually too thin for mining, except by stripping. Owing to the erosion of intervening areas it has been impossible to correlate these upper beds in different districts by continuous exposures, and though no individual bed is believed to have ever been continuous over the whole Arkansas coal field, it is thought that they are all within 100 feet of the same horizon. Such upper coals have been mined locally near Fort Smith, Central, Charleston, Caulksville, and Alma, and in the Philpott basin. Their outcrops have been seen in many other places. In general the coal is of good quality and as compared with the Hartshorne coal relatively free

from ash, though on weathering much of it is coated with white efflorescence.

Coals of this horizon are best exposed in the vicinity of Charleston, Franklin County, where they have been worked by stripping at many places indicated on the map (Pl. IX, p. 138). In general, the beds have roofs and floors of sandstone or sandy shale. One of the best exposures is at the west end of Coal Ridge, in sec. 15, T. 7 N., R. 30 W., 2 miles north of Auburn, where the coal occurs in a group of thin sandstones with intervening sandy shales. It has been mined from a succession of small slopes on a bed about 100 feet below the sandstone forming Coal Ridge. The bed is 18 inches thick and is without partings. About 60 feet above the bed mined there is a smaller bed which is of no importance here, but is probably of greater thickness elsewhere. Some of the many outcrops near Charleston represent this small upper bed, while others represent the lower.

East and north of Charleston there are on one or the other of these beds many openings which do not require description in detail, their positions being shown on the map. Two miles east of Charleston, on the Carter place, the bed is reported to be 3 feet thick in a slope from which more or less coal is taken every year. The same coal is probably represented in an old pit in sec. 3, T. 7 N., R. 27 W., 1 mile east of Caulksville, where it is reported to be only 13 or 14 inches thick.

Coal of the same horizon outcrops at a number of places between Charleston and Fort Smith, the best-known locality being in sec. 1, T. 7 N., R. 31 W., near Central, where there are several strip pits, small shafts, and slopes. The bed here has a thickness of about 20 inches without parting. The same coal has been penetrated by wells at a number of points in the region southwest of Central and has been mined from strip pits near Little Vache Grasse Creek and probably at other places.

The coal at the old Herman pit in sec. 2, T. 8 N., R. 22 W., near Fort Smith, is probably also at this horizon. It is said to have been worked before and during the civil war and is noted in the Arkansas Survey reports. Ten inches of good coal overlain by 1 foot of bony coal is exposed in the old workings. The bed is contained in sandy shale resembling that near Charleston.

Coal probably of the same horizon outcrops at several points on the north side of the river near Alma, the thickness of the bed nowhere exceeding 14 inches and usually averaging 9 or 10 inches. The same bed is thought to outcrop on Arkansas River at Moores Rock in T. 8 N., R. 30 W., and it has probably also been found in wells at Van Buren. None of these openings expose a coal of workable thickness.

A coal bed at this horizon probably occurs in Sugarloaf and Poteau mountains, where the exposures seen do not indicate that it has sufficient thickness to make it of commercial value.

At Paris this horizon is from 200 to 400 feet below the surface, and its outcrops north and south of the Paris basin have not been seen. In the Prairie View region, however, a coal bed 9 or 10 inches thick at about the proper distance above the horizon of the Hartshorne coal has been examined at a number of localities, which are noted on the map (Pl. IX). In no place has it been found to be of sufficient thickness to give it economic value under present conditions.

The bed mined at the old Philpott and Moomaw openings in T. 10 N., R. 26 W., also seems to correspond approximately in stratigraphic position with the Charleston bed. It lies in a synclinal basin 4 miles long by 2 miles wide, in which the rocks dip at low angles and the coal is nowhere very deep. At the Philpott slope, in sec. 20, T. 10 N., R. 25 W., the bed is from 18 to 22 inches thick without partings, and a similar thickness is reported from other openings. The coal is semibituminous and analyses of samples taken by the Arkansas Geological Survey indicate that it is comparatively low in ash and is chemically of a somewhat higher grade than the coal from the Pickartz bed.[a] Most of the product of one or two small mines is hauled by wagon to Ozark, where it is sold for domestic use.

COALS OF THE PARIS HORIZON.

The coal mined at Paris is from 1,200 to 1,400 feet above the Hartshorne horizon and about 400 feet below the top of the Paris shale. The coal bed is overlain by shaly sandstone and underlain by sandy shale. A few inches of draw slate usually comes down with the coal and there is in many places some fire clay between it and the sandy-shale floor. The bed is without parting and ranges in thickness from 2 to nearly 3 feet where it is worked. The whole area underlain by this coal does not exceed 8 square miles, and in its western part the bed is probably too thin for mining. The coal has a bright luster and a rather indefinite cubical fracture. Chemically it is semibituminous and somewhat higher in hydrocarbon than the average Hartshorne coals in the same region. It is sold principally for domestic use. All the coal mined is hand picked or forked, the slack being left in the gob.

Outside of the Paris district this coal horizon has not been discovered except in the vicinity of Potato Hill, where a thin bed provisionally correlated with it has been mined by stripping at several localities. West of Potato Hill, in sec. 23, T. 6, R. 27, the coal, as reported, is 14 inches thick and has been worked for local supply within the

[a] Ann. Rept. Arkansas Geol. Survey, 1888, vol. 3, p. 43.

last year. A similar coal outcrops in several localities near Pine Hill, but it is not mined to any extent and its thickness is not great enough to warrant development.

The same coal should outcrop in Sugarloaf, Poteau, and Magazine mountains, and it has probably been seen by prospectors and others in each of the first two localities, though it has not been reported from the last. On stratigraphic and paleobotanic evidence it is provisionally correlated with the McAlester coal of Indian Territory.

COALS BELOW THE HARTSHORNE HORIZON.

Coal beds have been reported from many localities in the shales and sandstones underlying the Hartshorne, to which the name Atoka formation has been applied. These lower coal beds are not continuous for any great distances and are thin except in small areas.

In the western part of the field such coal has been reported to the writer at only one locality, which is in the center of the Backbone anticline about 2 miles northeast of Hackett. The bed is between 500 and 1,000 feet below the Hartshorne sandstone and is not more than a few inches in thickness. Coal is also reported by the Arkansas Geological Survey [a] in the neighborhood of Booneville on Fletcher Creek, the locality being known as the Carlan drift. Although not personally examined, this coal is also believed by the writer to be several hundred feet below the Hartshorne sandstone.

A small bed of coal which has been mined from strip pits for local use outcrops on a bench on the north side of Rich Mountain 4 miles southwest of Ellsworth, in T. 7 N., R. 24 W. It is estimated to be from 300 to 400 feet below the Hartshorne sandstone. What is believed to be the same bed of coal has been penetrated by two drill holes near Shoal Creek in T. 7 N., R. 23 W., where it is 400 feet below the Hartshorne coal horizon and has a thickness of nearly 4 feet, but is divided by shale partings.

Similar coal beds outcrop at several localities south of the Shinn basin, in the Russellville district. The rocks here strike approximately east and west and dip to the north under the Shinn basin at high angles. It is probable that two beds are represented, one about 400, the other from 800 to 1,000 feet below the Hartshorne. Prospecting with diamond drills was in progress here during the summer of 1906, though at the time the region was visited no coal thick enough to work under present conditions had been discovered.

In the region south and southeast of Dardanelle the same beds have been worked occasionally since the days before the war. Some old excavations in sec. 35, T. 6 N., R. 21 W., north of Centerville, expose from 18 to 20 inches of coal at the outcrop. Several drill holes which have been sunk on this bed indicate that it is at least

[a] Ann. Rept. Arkansas Geol. Survey, 1888, vol. 3, pp. 23, 59, 80.

2½ feet thick in some places. The structure is such that this bed should dip northward into an extensive synclinal basin, and should crop out again a few miles south of Dardanelle. Its northern outcrop, however, has not been recognized. Near the center of this syncline a higher bed of coal has been opened in one or two wells and is reported to have a thickness of 14 to 15 inches. These beds are estimated to be about 400 feet and from 800 to 1,000 feet, respectively, below the Hartshorne sandstone. What is probably equivalent to the lower bed has been mined near Chickalah, south of Mount Nebo, and its occurrence west of Spring Mountain has been noted in the report of the Arkansas Geological Survey, but neither of these localities was examined. A coal that must also belong to one of the lower horizons has been reported near Atkins, in T. 7 N., R. 18 W., and near Galla Rock, in T. 6 N., R. 20 W.

Several thin coal beds occurring in rocks below the Hartshorne outcrop north of the Coal Hill district and also in the vicinity of Ozark, but none of these are of workable size where exposed.

From present indications further investigation of such beds in the vicinity of Russellville and Dardanelle is certainly justified and will probably result in extending the boundaries of the coal field as at present defined.

CHARACTER OF THE COAL.

The Arkansas coals usually have a bright luster when freshly mined, though parts of some of the beds in a few places are described as dull. There is as a rule no pronounced cleavage parallel to the bedding, but the vertical cleavage or cleat is complex and somewhat indefinite. Except possibly in a very few mines the cleat is not considered in mining, entries and rooms being driven without regard to any inherent structure, though the many cleavage planes affect the value of the coal, making it fragile. As mined, all these coals yield from 10 to 40 per cent of slack, the proportion of which is probably an index of the relative hardness of the coal at the different mines. Mine-run coal in the Jenny Lind, Greenwood, and Huntington districts, at the west end of the field, contains from 20 to 40 per cent of slack, whereas in the Russellville district, at the east end of the field, the slack does not average more than 10 per cent. This condition is, however, in part due to the method of mining, a lower percentage of slack being produced by hand or pick mining than by shooting off the solid.

The coals from the Jenny Lind and the Huntington and Greenwood districts, at the west end of the field, are classed as high-grade bituminous and semibituminous; those from the Coal Hill and Denning and the Paris districts are semibituminous, and those from the Spadra and the Russellville districts, at the east end of the field, are

semianthracite. One of the chief advantages of Arkansas coal is that in burning it produces relatively little smoke.

The agents of the fuel-testing plant at the Louisiana Purchase Exposition in 1904 collected mine and car samples from four representative mines in various parts of the Arkansas field. In sampling the mines a systematic method was followed in all cases, making the samples as nearly uniform as possible.[a]

The same method was observed by the Geological Survey party during the last season in collecting samples from the various mines. Proximate analyses were made at the fuel-testing plant of all the samples collected, and ultimate analyses and other special tests were made of a few representative samples from the various districts. The results obtained with the fuel-testing plant samples have already been published, and a full account of the subsequent analyses will appear in the bulletin from which this paper is abstracted.

For purposes of comparison the proximate analyses of representative samples of Arkansas coal have been recalculated to an air-dried basis and are given in the following table:

Analyses of coal samples from Arkansas.

[F. M. Stanton, analyst.]

District and character of coal	Bates-Coaldale; bituminous.	Greenwood-Huntington; bituminous and semibituminous.							
Nearest town	Bates.	Hartford.	Huntington.	Burma.			Montreal.		Fidelity.
Laboratory No.	3505.	3500.	1114.	3154.	3158.	3155.	3150.	3152.	3175.
Analysis of sample as received:									
Prox. Moisture	3.37	4.12	3.24	2.44	2.65	3.54	3.01	2.57	2.26
Prox. Volatile matter	24.44	18.15	17.46	16.85	15.70	14.89	15.75	15.48	15.79
Prox. Fixed carbon	66.40	69.97	66.69	74.98	74.52	74.88	75.93	76.17	71.91
Prox. Ash	5.79	7.76	12.61	5.73	7.13	6.69	5.31	5.78	10.04
Ult. Sulphur	.87	.98	1.24	2.57	2.86	1.21	.93	2.05	1.20
Ult. Hydrogen			4.15						
Ult. Carbon			74.09						
Ult. Nitrogen			1.44						
Ult. Oxygen			6.47						
Calorific value determined:									
Calories			7,294						
British thermal units			13,129						
Loss of moisture on air drying	2.50	3.40	2.10	1.60	1.90	2.70	2.20	1.80	1.60
Analysis of air-dried sample:									
Prox. Moisture	.89	.75	1.17	.85	.76	.86	.83	.78	.67
Prox. Volatile matter	25.07	18.79	17.83	17.13	16.01	15.30	16.10	15.76	16.05
Prox. Fixed carbon	68.10	72.43	68.12	76.20	75.96	76.96	77.64	77.57	73.08
Prox. Ash	5.94	8.03	12.88	5.82	7.27	6.88	5.43	5.89	10.20
Ult. Sulphur	.89	1.01	1.27	2.61	2.92	1.24	.95	2.09	1.22
Ult. Hydrogen			4.00						
Ult. Carbon			75.68						
Ult. Nitrogen			1.47						
Ult. Oxygen			4.70						
Calorific value determined:									
Calories			7,450						
British thermal units			13,410						
Fuel ratio	2.72	3.86	3.82	4.45	4.75	5.05	4.87	4.92	4.55

[a] Report on the operations of the coal-testing plant: Prof. Paper U. S. Geol. Survey No. 48, 1906, pt. 1, p. 33.

Analyses of coal samples from Arkansas—Continued.

District and character of coal	Greenwood-Huntington; bituminous and semibituminous.			Bonanza-Jenny Lind; bituminous and semibituminous.				Charleston; bituminous.	Paris; semibituminous.
Nearest town	Greenwood.	Excelsior.	Hackett.	Bonanza.	Jenny Lind.		Fort Smith.	Auburn.	Paris.
Laboratory No.	3173.	3157.	3497.	1160.	1115.	3153.	3372.	3218.	3174.
Analysis of sample as received:									
Prox. Moisture	3.21	3.64	3.55	2.23	1.60	3.18	2.19	3.80	2.77
Prox. Volatile matter	14.84	16.57	17.16	16.02	17.40	14.64	14.00	15.96	14.69
Prox. Fixed carbon	72.66	76.00	75.46	72.55	73.09	76.06	72.15	75.86	73.47
Prox. Ash	9.29	3.79	3.83	9.20	7.91	6.12	11.66	4.38	9.07
Ult. Sulphur	3.12	.83	.96	1.87	1.42	1.51	2.06	2.21	2.79
Ult. Hydrogen	3.75	.....	.....	4.24	.....	.....	.....	.....	4.02
Ult. Carbon	78.37	.....	.....	78.83	.....	.....	.....	.....	78.71
Ult. Nitrogen	1.52	.....	.....	1.38	.....	.....	.....	.....	1.46
Ult. Oxygen	3.95	.....	.....	4.48	.....	.....	.....	.....	3.95
Calorific value determined:									
Calories	7,549	.....	.....	7,639	7,868	.....	.....	.....	7,652
British thermal units	13,588	.....	.....	13,750	14,162	.....	.....	.....	13,774
Loss of moisture on air drying	2.40	3.00	2.80	1.50	.80	2.40	1.40	2.60	2.20
Analysis of air-dried sample:									
Prox. Moisture	.83	.66	.77	.74	.81	.80	.80	1.23	.59
Prox. Volatile matter	15.20	17.03	17.66	16.26	17.54	15.00	14.20	16.39	15.02
Prox. Fixed carbon	74.45	78.35	77.63	73.66	73.68	77.93	73.17	77.89	75.12
Prox. Ash	9.52	3.96	3.94	9.34	7.97	6.27	11.83	4.49	9.27
Ult. Sulphur	3.20	.85	.99	1.90	1.44	1.58	3.09	2.27	2.85
Ult. Hydrogen	3.56	.....	.....	4.13	.....	.....	.....	.....	3.87
Ult. Carbon	80.30	.....	.....	80.03	.....	.....	.....	.....	80.48
Ult. Nitrogen	1.56	.....	.....	1.40	.....	.....	.....	.....	1.49
Ult. Oxygen	1.86	.....	.....	3.20	.....	.....	.....	.....	2.04
Calorific value determined:									
Calories	7,735	.....	.....	7,756	7,931	.....	.....	.....	7,824
British thermal units	13,923	.....	.....	13,961	14,275	.....	.....	.....	14,084
Fuel ratio	4.90	4.59	4.40	4.52	4.20	5.20	5.15	4.75	5.00

District and character of coal.	Denning-Coal Hill; semibituminous.			Spadra; semianthracite.			Russellville; semianthracite.	
Nearest town	Coal Hill.		Altus.	Spadra.		Clarksville.	Russellville.	
Laboratory No.	1130.	3370.	3371.	3368.	3407.	3369.	3177.	3176.
Analysis of sample as received:								
Prox. Moisture	1.38	3.41	3.77	2.11	2.15	1.72	2.33	2.07
Prox. Volatile matter	14.76	12.10	13.96	11.42	10.82	10.46	10.60	9.81
Prox. Fixed carbon	76.91	78.41	79.35	77.83	76.87	79.50	77.67	78.82
Prox. Ash	6.95	6.08	2.92	8.64	10.16	8.32	9.40	9.30
Ult. Sulphur	1.52	4.05	.74	1.99	2.30	2.49	1.81	1.74
Ult. Hydrogen	.....	.....	.....	.....	.....	.....	.....	3.62
Ult. Carbon	.....	.....	.....	.....	.....	.....	.....	80.28
Ult. Nitrogen	.....	.....	.....	.....	.....	.....	.....	1.47
Ult. Oxygen	.....	.....	.....	.....	.....	.....	.....	3.59
Calorific value determined:								
Calories	7,961	.....	.....	7,693	.....	7,704	.....	7,612
British thermal units	14,330	.....	.....	13,853	.....	13,867	.....	13,703
Loss of moisture on air drying	.70	2.40	2.80	1.00	1.40	.70	1.60	1.40
Analysis of air-dried sample:								
Prox. Moisture	.68	1.03	1.00	1.12	.76	1.03	.74	.68
Prox. Volatile matter	14.87	12.39	14.36	11.54	10.97	10.53	10.77	9.95
Prox. Fixed carbon	77.45	80.35	81.64	78.61	77.96	80.06	78.94	79.94
Prox. Ash	7.00	6.23	3.00	8.73	10.31	8.38	9.55	9.43
Ult. Sulphur	1.53	4.15	.76	2.01	2.33	2.51	1.84	1.76
Ult. Hydrogen	.....	.....	.....	.....	.....	.....	.....	3.51
Ult. Carbon	.....	.....	.....	.....	.....	.....	.....	81.42
Ult. Nitrogen	.....	.....	.....	.....	.....	.....	.....	1.49
Ult. Oxygen	.....	.....	.....	.....	.....	.....	.....	2.39
Calorific value determined:								
Calories	8,017	.....	.....	7,693	.....	7,758	.....	7,720
British thermal units	14,431	.....	.....	13,853	.....	13,965	.....	13,896
Fuel ratio	5.21	6.48	5.68	6.82	7.11	7.59	7.33	8.04

CONDITIONS OF MINING AND DEVELOPMENT.

Production.—The development of the coal industry in Arkansas on a commercial scale was started about 1870, and the production increased to a maximum of 2,229,172 short tons in 1903. A slight decline in the production after 1903 was caused by the competition of fuel oil from Texas, but present conditions indicate that the demand for Arkansas coal is again increasing.

Method of mining.—Coal was first obtained in Arkansas by stripping, and a few pits of this kind are still in operation, though most of the coal is mined from deeper workings reached either by slopes or shafts. The majority of these mines are shallow, averaging less than 200 feet in depth. A 480-foot shaft in the Shinn basin, at the east end of the field, reaches the maximum depth.

The room and pillar system prevails, with some local modification throughout the field, the pillars not being drawn. The actual mining of the coal is generally done by shooting it off the solid face of the bed. Undercutting by hand is the method employed in a few mines where the coal is of unusually good quality. No mining machines are used in the field.

In the larger mines haulage from the rooms is by mules and in the main gangway either by mules or cable. One of the mines at Bonanza is equipped with electric motors.

Ventilation in the larger mines is accomplished by fans, and in the smaller ones by fire boxes. There is comparatively little gas, and accidents from this cause are relatively rare.

Minimum thickness of workable coal.—The minimum thickness of coal mined for shipment is slightly over 2 feet, and some coals as thin as 18 inches are mined for local markets.

Preparation of coal for market.—The coal is sold either as mine run, including both lump and slack, or, most commonly, it is passed over screens which separate it into lump and slack. At a number of the smaller mines the lump coal is separated by hand with a fork, and the slack is left in the gob.

Labor.—Practically all the coal is mined under contract at a definite rate per ton, established by an agreement between the operators and the miners' union. There are no nonunion miners in the field. During 1904 and 1905 the Arkansas coal-mining industry was not interrupted by the strikes which prevailed in other States, but in 1906 all the principal mines were shut down from the first of April to the first of July.

THE GREAT FALLS COAL FIELD, MONTANA.[a]

By Cassius A. Fisher.

INTRODUCTION.

The present paper is a brief preliminary statement of the results of a detailed survey made of the Great Falls coal field, Montana, during the season of 1906 by W. R. Calvert, H. M. Eakin, and the writer. The principal resource of this region is coal, and, as the investigation was made primarily to determine the classification of the public lands, the work was conducted with a view to defining as far as practicable the limits of the coal areas with respect to legal subdivisions of such lands.

The Great Falls coal field was first examined by geologists of the Transcontinental Survey in 1879. In the course of this investigation the coal-bearing horizon was studied and traced from Judith River to Belt Creek by the late George H. Eldridge.[b] Later a brief examination was made of this coal field by J. S. Newberry[c] in the interests of the Great Northern Railway. During the spring of 1891 W. H. Weed, while making an examination of the coal field of Montana for the United States Geological Survey, visited this region and later described the deposits in considerable detail.[d]

LOCATION.

The Great Falls coal field is situated along the base of the Rocky Mountain front range in north-central Montana. As first described by Weed, it extends as a zone of comparatively narrow width along the base of the Rocky Mountains from a point near Musselshell River northwestward to the international boundary line between Canada and the United States. While coal-bearing rocks of Lower and Upper Cretaceous age occur throughout this area, more detailed investigation of the field during the last season has shown that coal beds of commercial importance lie mainly to the east of Missouri River. West and north of that stream to Teton River the coal beds are, so far

[a] A full account of this coal field is being prepared and will appear as a separate publication of the Geological Survey.

[b] Eldridge, George H. Montana coal fields: Tenth Census of the U. S., vol. 15, 1880, pp. 740-757.

[c] Newberry, J. S., The Great Falls coal field: School of Mines Quarterly, vol. 8, 1887, No. 4.

[d] Weed, W. H., Two Montana coal fields: Bull. Geol. Soc. America, vol. 3, 1892, p. 304.

as observed, of less than workable thickness. Although no detailed examination was made of the area bordering the Lewis Mountains north of Teton River, the best information that could be obtained indicates that this area does not contain coals of commercial importance.

Within that portion of the Great Falls coal field which lies between Missouri and Judith rivers, where the present investigation was made, there are three districts underlain by workable coal. For convenience, these are here designated the Sage Creek, Otter Creek, and Sand Coulee districts. In the following discussion the term Great Falls coal field is used in the more limited sense, as applying to the field east of Missouri River. (See Pl. X.)

TOPOGRAPHY.

The Great Falls coal field lies in a region whose topography is transitional between that of the plains and that of the mountains, including areas characteristic of both provinces. Its salient features are broad, gentle slopes and plateaus bordering the adjacent mountain ranges. These plateaus are traversed by numerous mountain streams which flow through deep and relatively narrow valleys, especially in that portion of the district lying west of the Otter Creek divide. East of this divide the valleys are relatively narrow throughout a zone bordering the Little Belt Mountains, but farther out on the plains, where they have developed in softer Cretacous rocks, they are usually wide and open. Along the southern margin of the district, from Smith River to the head of Otter Creek, the surface of the plains rises gradually by sloping plateaus, culminating in a zone of high, hilly country bordering the Little Belt Mountains, which lie to the south. West of Missouri River the surface rises by successive plateaus toward the base of the Lewis Range.

There is a moderate range of altitude within the area described. The highest points are along the base of the Little Belt Mountains, where the more prominent summits reach altitudes of 4,500 to 5,000 feet. The lowest point in the district is along Missouri River below the Big Falls, at an elevation of about 3,000 feet above sea level. The average altitude of the region is between 3,500 and 4,000 feet. The extreme variation of altitude for any given locality is about 1,300 feet in a horizontal distance of 1½ miles. This difference of elevation is found between Belt Creek and the summit of Belt Butte at the town of Belt. The relative differences in altitude of valley bottoms and plateau summits range from 300 to 600 feet.

GEOLOGIC OCCURRENCE OF COAL.

Throughout the Great Falls coal field coal occurs in the lower part of the Kootenai (Lower Cretaceous) formation, mainly at one horizon,

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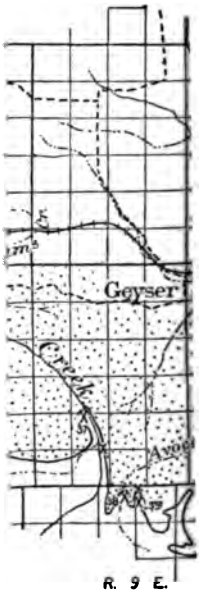

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which is 60 feet above the base of the formation. Coal of workable thickness is not continuous, however, at this horizon, but varies locally. The Kootenai formation has a thickness of about 475 feet and consists mainly of sandstones and sandy shales occurring in alternate succession. In the lower part sandstones predominate and are massive in character, but higher in the formation the proportion of sandstone decreases, and the beds consist largely of red shales and clays with here and there a thin layer of sandstone. The formation rests with apparent conformity upon the variegated sandy shale and sandstone of the Morrison and is overlain by the somber-colored shale and sandstone of the Colorado formation. A generalized section of the sedimentary rocks of the Great Falls coal field is given below:

Generalized section of sedimentary rocks in Great Falls coal field.

	Feet.
Colorado formation (Upper Cretaceous):	
Shale, dark gray, sandy, with thin layers of sandstone	80
Sandstone, dark gray	10
Volcanic ash	30
Shale, dark colored, sandy, with thin layers of sandstone	80
Shale, sandy, or impure sandstone	20
Shale, dark, sandy	75
Sandstone, gray, forming belt around Belt Butte	50
Shale, dark, sandy	80
Shale, dark, sandy in lower part	125
Shale, dark, sandy, containing massive sandstone members, locally calcareous at top	180
Kootenai formation (Lower Cretaceous):	
Shale, red, sandy, and clay, with few thin sandstone layers	195
Shale, red, sandy, capped by sandstone	20
Limestone	5
Shale, red, sandy, capped by sandstone	20
Shale, red, sandy at top	30
Shale, red, sandy, with here and there a thin sandstone layer	50
Shale, red, containing lenses of impure limestone and capped by gray limestone	30
Sandstone, gray, massive	40
Coal and coaly shale	10
Sandstone and sandy shale	60
Morrison formation (Jurassic?):	
Sandstone, gray	25
Shale, sandy, variegated, containing thin layers of sandstone and limestone	75
Ellis formation (Jurassic):	
Sandstone, massive, gray, weathering light brown, conglomeratic at base	100

The foregoing section is compiled from a number of detailed measurements made in various parts of the field, and as individual beds vary materially in different localities it can not be regarded as typical of any one locality. It is introduced here mainly to show the succession of the beds and the position of the coal in the stratigraphic column.

The geologic structure of the coal field is comparatively simple. The rocks dip, at relatively small angles, to the northeast, away from the adjoining mountains. In a narrow zone bordering the Little Belt Range the rocks dip from 10° to 15°, but in their extension toward the plains they flatten rapidly, and in the area underlain by coal the dips rarely exceed 4°. An exception to this occurs in the vicinity of Skull Butte, where a local doming of the sediments, probably due to a laccolithic intrusion of igneous rock, increases the dip to 25°. A close examination of the canyons throughout the coal area, where the dips are low and in general to the north, shows that these nearly horizontal beds are in reality gently folded into a series of low anticlines and shallow synclines, most of which are not perceptible to the casual observer. Minor faults are also more or less common throughout the coal area, especially in the vicinity of Belt, where they have caused some difficulty in mining the coal.

The irregularity in the occurrence of workable coal at the horizon above referred to is a characteristic feature of the beds of this field that was observed early in the investigation, and an effort was made to trace out, as far as possible from a study of the outcrop, the limits of the areas underlain by workable coal. These coal areas or basins, as they have been previously designated, are three in number and include a total area of approximately 316 square miles. The largest, comprising about 230 square miles, lies south of Great Falls, extending from a point a short distance east of Belt Creek westward beyond Smith River. (See Pl. X.) It is possible, however, that the coals of this basin continue southward throughout the territory lying between the Big and Little Belt mountains, but no examination was made of this region. The district examined is drained by Sand Coulee and its tributaries and is known as the Sand Coulee basin. To the east the next district underlain by coal of commercial importance lies between Little Otter and Geyser creeks and is designated Otter Creek basin. This is the smallest coal basin in the district, including only about 38 square miles. Still farther east, in the vicinity of Skull Butte, there is a third coal basin which, owing to its nearness to Sage Creek, the main drainage channel of the district, is called the Sage Creek basin. It includes about 48 square miles.

DETAILED DESCRIPTION OF COAL DEPOSITS.

SAND COULEE BASIN.

GENERAL CONDITIONS.

The Sand Coulee basin is underlain by one coal-bearing bed of commercial importance. In this bed, consisting of coal interbedded with

layers of bone, shale, and clay, the coal content ranges in thickness from 6 to 14 feet in different parts of the field. At Belt, near the northeast end of the basin, where the bed has been opened at many places, the average thickness of twenty-six measured sections is 4 feet 7 inches. At Sand Coulee fourteen measured sections give an average thickness of 8 feet 7 inches, and along Smith River, where fewer openings have been made, an average of five sections shows a total thickness of 7 feet 6 inches of coal. In the vicinity of Belt the coal is divided into three distinct benches. The lower and upper benches are about equal in thickness; the middle bench is considerably thinner. A section of the coal bed in the Anaconda Copper Mining Company's mine, which may be regarded as representative of the Belt Creek mines, is given below:

Section of coal bed in Anaconda Copper Mining Company's mine, Belt.

	Ft.	In.
Coal	1	9
Bone		8
Coal		5
Bone		4
Coal	2	8
	5	10

At Sand Coulee the arrangement of the coal beds is somewhat different. Here the coal mined occurs in two principal benches, the upper much thicker than the lower, but between these two there is no middle bench, such as occurs in the Belt Creek mines. Above the upper bench, however, there are two higher layers of coal which have a maximum measured thickness of 5 feet 8 inches. These two higher coals are not mined in the Smith River region, where the number and arrangement of the coal benches are similar to those of the Sand Coulee district. The following are representative sections of the coal bed in the Sand Coulee and Smith River districts:

Section of coal bed in Cottonwood Coal Company's mine, Stockett.

Sandstone.	Ft.	In.
Coal		10
Bone		4
Coal	1	10
Bone		7
Coal	6	1
Bone		6
Coal	2	6
	12	8

Section of coal bed in Lofe's mine, near Eden.

	Ft.	In.
Coal	3	
Bone		10
Coal	1	6
Bone		8
Coal	3	
Bone	1	6
Coal	1	2
Shale.		
	11	8

From a comparison of the average thickness, number, and order of the various coal benches in the Belt, Sand Coulee, and Smith River mining districts, it is apparent that the coals of this basin are of lenticular character and that the total thickness of coal contained in the coal-bearing zone is greatest at the Sand Coulee mines.

DEVELOPMENT.

GENERAL STATEMENT.

Development of the coal resources of the Great Falls coal field was first begun in the Sand Coulee basin at Belt, where, in 1876, a small mine was opened and coal shipped overland to Fort Benton, a town situated near the head of navigation on Missouri River. For the first few years the coal output of this district was small, but with the opening of mines at Sand Coulee and on Smith River, which took place a few years later, the amount was increased. In 1885 the combined production of the Belt and Sand Coulee mines was 1,900 tons, of which 1,200 tons were from the Belt mines. During the following year the output of these two localities amounted to only 1,400 tons, the greater part being supplied by the Sand Coulee mines. The reports from Cascade County for 1887 give a relatively small yield, but during the following year, with the completion of the railroad to Sand Coulee, the total coal production of the region was materially increased. From 1888 to 1892 the annual coal output of the Sand Coulee basin increased steadily, but with the improvements made in the facilities for handling coal at the Sand Coulee mines during 1893, the total production of the region was increased over 100 per cent. Since 1880, when the first systematic record of the coal production of Montana was kept, Cascade County has been one of the largest producing counties in the State. Its output, together with that of the State, is shown in the following table:

Coal production of Montana and Cascade County from 1880 to 1906, inclusive.[a]

[Short tons.]

Year.	Montana.	Cascade County.	Year.	Montana.	Cascade County.
1880	224	.....	1895	1,504,193	713,877
1881	5,000	.....	1896	1,543,445	1,101,298
1882	10,000	.....	1897	1,647,882	1,138,590
1883	19,795	.....	1898	1,479,803	988,821
1884	80,376	.....	1899	1,496,451	965,378
1885	86,440	1,900	1900	1,661,775	1,123,395
1886	49,846	1,400	1901	1,396,081	789,407
1887	10,202	.....	1902	1,560,823	761,572
1888	41,467	4,600	1903	1,488,810	733,064
1889	363,301	166,480	1904	1,358,919	599,158
1890	517,477	200,435	1905	1,643,832	826,026
1891	541,861	198,107	1906	1,838,635	991,417
1892	564,648	242,120			
1893	892,309	516,460		22,730,990	12,702,465
1894	927,395	638,960			

[a] Mineral Resources U. S., 1880–1906, U. S. Geol. Survey.

Although at present coal prospects and small mines are located at many different places throughout the Sand Coulee basin, development is confined chiefly to the three localities where stream valleys crossing the district cut and expose the coal-bearing rocks. These districts of principal development are along Belt Creek, Sand Coulee, and Smith River.

BELT CREEK MINES.

Along Belt Creek and its tributaries near the town of Belt the coal bed has been extensively prospected and a number of mines are now being operated. The mine of the Anaconda Copper Mining Company is the largest in the district. In addition to this mine there are four smaller ones, which are worked continuously, and seven abandoned mines, some of which have produced considerable coal in the past. Prospecting has been extensive, especially along Nell Creek, on either side of Belt Creek, and in Armington Coulee. A number of diamond-drill prospect holes have been bored by the larger companies on the plateau west of Belt Creek in order to determine the character of the coal bed underlying their respective holdings.

SAND COULEE MINES.

Four coal companies are now operating along Sand Coulee and its tributary canyons in the vicinity of Stockett. These are the Cottonwood Coal Company at Stockett, the Nelson and Gerber coal companies at the town of Sand Coulee, and the Mount Oregon Coal Company. In addition there are a number of prominent individual producers. Those deserving of special mention are Dahn, Brown, and Stamsby mines. This locality was the second to receive attention in the development of the coal resources of the Great Falls coal field, but at present it is the largest producing district of the entire field and one of the largest in the State.

Branch railroad lines connect Stockett and Sand Coulee with the Neihart branch of the Great Northern Railway at Gerber station, and a large amount of coal is shipped from these towns to Great Falls and

also to more distant points along the Great Northern main line, both to the east and west.

SMITH RIVER MINES.

In the bluffs bordering Smith River and its tributaries, Hound Creek and Ming Coulee, the coal-bearing zone is exposed at many places. The coal has been mined intermittently throughout this district for over twenty-five years, and within the last decade extensive prospecting has been done in order to ascertain the extent of the coal bed in this portion of the Sand Coulee basin. Several small mines are now operated, and there are a few abandoned mines from which coal is occasionally taken. Those worked are the Gibson, Carville, Patterson, Bickett, and Lofe mines. These have a combined annual output of only a few hundred tons. The location of prospects and mines in this part of the Sand Coulee basin is shown on Pl. X (p. 162).

OTTER CREEK BASIN.

GENERAL CONDITIONS.

The Otter Creek coal basin, which is located southwest of Geyser, extending along Otter Creek for a distance of about 10 miles, lies mainly in T. 17 N., Rs. 8 and 9 E., but includes a small portion of T. 16 N., R. 9 E. It occupies a total area of about 38 square miles. The southern limits of the basin are definitely marked by the southern outcrop of the coal-bearing rocks, but to the east, north, and west the extent of the coal can only be inferred from a study of a comparatively small number of exposures. The limits of the basin thus determined are indicated in Pl. X. The Otter Creek basin is underlain by one bed of coal which ranges in thickness, as indicated by exposures, from 3 to 6 feet. The maximum thickness, however, in the center of the basin probably exceeds 6 feet. The coal generally occurs in two benches, although at one mine three distinct benches were observed. The maximum thickness of workable coal is 4 feet, as shown by the section at Nollar's mine, where it occurs in one bed with no partings. At other openings where two benches are present the lower is usually the thicker and contains the better quality of coal. The parting between the two benches is commonly bone. In the locality where three benches occur their total thickness is 2 feet 3 inches. It is difficult to give an average coal section of the Otter Creek basin, for only one mine has been opened which may be regarded as representative of the coal in the central part of the basin. This mine, owned by Mr. Nollar, shows a total thickness of 4 feet, as above stated. It is probable that over a considerable area the coal retains this thickness, but throughout the marginal portions it doubtless becomes much thinner.

DEVELOPMENT.

The coals of the Otter Creek basin have not been mined to any extent. Some coal has been taken out of different openings for a

number of years, but the basin as a whole is practically undeveloped. The Billings and Northern Railroad, now being constructed, will pass near the northern edge of the field, thus affording transportation facilities for coal mined in the future. At the present time only three small mines are worked in the district—the Nollar, Nullinger, and Chambers mines. Of these, only the Nollar mine is of sufficient size to be regarded as a factor in the production of coal in this district.

SAGE CREEK BASIN.

GENERAL CONDITIONS.

The Sage Creek basin, situated in the eastern part of the Great Falls coal field, a few miles south of Stanford, in the vicinity of Skull Butte, lies mainly in Tps. 15 and 16 N., Rs. 11 and 12 E., but embraces portions of Tps. 15 and 16 N., R. 13 E. The area described encircles Skull Butte, a dome-shaped uplift which exposes rocks older than the coal-bearing measures. This basin ranks second in the field in point of size, being slightly larger than the Otter Creek basin and considerably smaller than the Sand Coulee basin. It includes about 48 square miles.

So far as known, there is only one coal bed in this basin. Its thickness, including partings, ranges from 6 to 18 feet. Within this thickness of beds deposited under coal-forming conditions the aggregate amount of coal ranges from 2½ to 7 feet, usually occurring in the form of three distinct benches, which are generally recognized by miners in the district. The lowest bench has a thickness of about 2 feet and is regarded as the best coal mined. Above this is commonly a parting 2 to 6 inches thick, overlain by the middle bench of coal, which is from 12 to 16 inches thick. Overlying the middle bench is generally 1 to 6 inches of bone, which is followed in turn by the upper bench of coal, ranging from 1 to 3 feet in thickness. The coal is usually covered by 1 to 2 feet of dark-colored shale, which forms the roof of the mine. Above the shale there are in many places impure coaly layers interbedded with brown and black sandy leaf-bearing shales having a thickness of several feet. The next member in ascending order is a gray, massive sandstone ranging in thickness from 20 to 60 feet. In the outer portion of the basin the base of this sandstone forms in places the roof of the mine. A section representative of the coal bed in this locality is given below:

Representative section of coal bed in Sage Creek basin.

	Ft.	In.
Coal	2	
Bone		4
Coal	1	2
Coal, bony	1	
Coal	2	
	6	6

DEVELOPMENT.

The coals of the Sage Creek basin have not been extensively developed. Coal has been mined in this vicinity for many years, but owing to the lack of transportation facilities the output has never exceeded an amount necessary to supply a small local demand. At the present time the Billings and Northern Railroad Company is building a road through this district, which will afford an outlet for the coal. Already a number of diamond-drill prospect holes have been bored along Sage Creek and its tributaries in order to ascertain the northern and eastern limits of the coal bed, and while the present investigation was being conducted plans were being made to continue diamond-drill prospecting in the vicinity. At the present time only three small mines, owned by Messrs. Schultz, Seman, and Hughes, are being worked. The Schultz and Seman mines are located near together on the west side of Spring Draw, in sec. 20, T. 15 N., R. 12 E. The annual output of the former is about 1,000 tons; that of the latter is somewhat smaller. Neither of these mines is well equipped. The Hughes mine has only recently been opened. Besides the above-mentioned mines there are four abandoned mines, known as the Fisher, Sage Creek Sheep Company, Corwin, and McGregor. The locations of the mines and prospects are shown on Pl. X (p. 162).

QUALITY OF COAL.

During the investigation of the coal resources of this field a number of samples were taken of the coal in different localities for the purpose of chemical analysis. These samples were collected in a uniform manner and in compliance with specifications issued by the fuel-testing plant of the United States Geological Survey. A channel was cut perpendicularly across the face of the coal bed from roof to floor of such a size as to yield at least 5 pounds of coal per foot of thickness of coal bed. All material encountered in this cut was included in the sample, except partings more than three-eighths of an inch thick and lenses or concretions of sulphur or other impurities greater than 2 inches in diameter. The coal thus obtained was pulverized sufficiently to pass through a sieve of ½-inch mesh, and after thorough mixing was divided into quarters, opposite quarters being rejected. This process was continued until the amount was reduced to about a quart sample. The material was then placed in a galvanized can, sealed by adhesive tape, and shipped to the chemical laboratory at St. Louis for analysis. The following table gives the result of these analyses:

Analyses of coal samples from Great Falls coal field, Montana.

[F. M. Stanton, analyst.]

	Sage Creek basin.		Otter Creek basin.		Sand Coulee basin. Belt district.			
Laboratory No.	3756.	3753.	3758.	3759.	3757.	3515.	3512.	3514.
Analysis of sample as received:								
Prox. Moisture	11.26	9.27	10.18	8.76	13.07	3.51	7.05	6.37
Prox. Volatile matter	25.85	29.57	24.82	25.72	21.79	26.39	25.47	27.55
Prox. Fixed carbon	46.49	45.90	45.25	50.36	43.26	50.60	49.34	45.20
Prox. Ash	16.40	15.26	19.75	15.16	21.88	19.50	18.14	20.88
Ult. Sulphur	4.56	3.96	3.01	3.91	1.30	3.74	1.67	2.04
Ult. Hydrogen	4.51	4.78	.....	4.40	4.23	4.13	4.36	3.92
Ult. Carbon	53.47	58.13	.....	58.93	49.[illegible]5	61.51	58.10	56.14
Ult. Nitrogen	.69	.79	.....	.79	.69	.68	.64	.73
Ult. Oxygen	20.37	17.08	.....	16.81	21.95	10.44	17.09	16.29
Calorific value determined:								
Calories	5,122	5,675	.....	5,626	4,639	6,045	5,623	5,481
British thermal units	9,220	10,215	.....	10,127	8,350	10,881	10,121	9,866
Loss of moisture on air drying	5.50	4.60	4.60	4.80	6.00	1.60	2.60	2.70
Analysis of air-dried sample:								
Prox. Moisture	6.09	5.00	5.85	4.16	7.52	1.93	4.57	3.77
Prox. Volatile matter	27.35	31.00	26.01	27.02	23.18	26.81	26.15	28.30
Prox. Fixed carbon	49.18	48.00	47.43	52.90	46.02	51.44	50.65	46.46
Prox. Ash	17.38	16.00	20.71	15.92	23.28	19.82	18.63	21.47
Ult. Sulphur	4.82	4.15	3.15	4.11	1.38	3.80	1.71	2.08
Ult. Hydrogen	4.12	4.48	.....	4.03	3.79	4.02	4.17	3.73
Ult. Carbon	56.57	60.93	.....	61.90	53.14	62.51	59.65	57.70
Ult. Nitrogen	.73	.83	.....	.83	.73	.69	.65	.74
Ult. Oxygen	16.38	13.61	.....	13.21	17.68	9.16	15.19	14.28
Calorific value determined:								
Calories	5,420	5,949	.....	5,910	4,951	6,094	5,824	5,633
British thermal units	9,756	10,707	.....	10,637	8,888	11,058	10,391	10,139

	Sand Coulee basin. Belt district.			Stockett-Sand Coulee district.		Smith River district.		
Laboratory No.	3755.	3513.	3754.	4115.	4119.	4118.	4117.	4114.
Analysis of sample as received:								
Prox. Moisture	9.58	4.62	10.88	6.01	7.49	4.82	6.17	4.54
Prox. Volatile matter	23.24	30.51	20.27	28.43	27.29	27.17	27.03	27.44
Prox. Fixed carbon	52.24	46.14	41.97	51.42	51.44	46.13	52.03	47.95
Prox. Ash	14.[illegible]4	18.73	26.88	14.14	13.78	21.88	14.77	20.07
Ult. Sulphur	2.00	3.59	1.79	2.38	2.32	2.84	4.36	4.09
Ult. Hydrogen	4.28	.....	3.72	4.46	4.68	4.36	4.43	4.23
Ult. Carbon	58.74	.....	47.37	63.61	62.21	56.98	61.62	58.66
Ult. Nitrogen	.67	.....	.52	.91	.88	.72	.93	.87
Ult. Oxygen	19.37	.....	19.72	14.50	16.13	13.22	13.89	12.08
Calorific value determined:								
Calories	5,518	.....	4,301	6,196	6,115	5,528	6,077	5,818
British thermal units	9,932	.....	7,742	11,153	11,007	10,040	10,939	10,472
Loss of moisture on air drying	5.00	2.10	5.40	2.40	2.60	1.90	2.20	1.70
Analysis of air-dried sample:								
Prox. Moisture	4.82	2.57	5.76	3.70	5.02	2.98	4.06	2.89
Prox. Volatile matter	24.46	31.17	21.42	29.13	28.02	27.69	2.763	27.91
Prox. Fixed carbon	55.00	47.13	44.42	52.68	52.81	47.03	53.20	48.79
Prox. Ash	15.72	19.13	28.40	14.49	14.15	22.30	15.11	20.41
Ult. Sulphur	2.10	3.70	1.89	2.43	2.38	2.90	4.46	4.13
Ult. Hydrogen	3.91	.....	3.30	4.33	4.51	4.24	4.25	4.18
Ult. Carbon	61.85	.....	50.08	65.17	63.88	58.08	63.02	59.66
Ult. Nitrogen	.70	.....	.55	.92	.89	.73	.95	.88
Ult. Oxygen	15.72	.....	15.78	12.66	14.19	11.75	12.21	10.74
Calorific value determined:								
Calories	5,808	.....	4,546	6,348	6,278	5,678	6,213	5,918
British thermal units	10,454	.....	8,184	11,427	11,300	10,244	11,185	10,654

These analyses show that the coals of the Great Falls region are to be regarded as medium grade bituminous. They contain on an average about 49 per cent of fixed carbon, 26 per cent of volatile matter,

18 per cent of ash, and 3 per cent of sulphur. The sulphur occurs largely in the form of iron-pyrite nodules which, together with other impurities, are present in such abundance as to render it necessary to wash the coal before placing it on the market. The sulphur nodules, after being separated from bone, shale, and other impurities, are sold as a by-product to the large smelters at Anaconda, Mont., where they are utilized in the process of pyritic smelting.

FUTURE DEVELOPMENT OF THE GREAT FALLS COAL FIELD.

The Great Falls coal field, owing to its geographic position and relation to other coal fields, is destined to remain one of the most important coal-mining districts of Montana. The territory which this field may be expected to supply with coal in the future lies mainly to the north and northwest. To the southeast there are a number of coal localities along Musselshell River which, with the development of proper railroad facilities, would probably become large coal-producing districts. Throughout the area bordering the Great Falls coal field on the north different conditions prevail. Here, although coal-bearing rocks occupy extensive areas both to the northeast in the vicinity of Havre and to the northwest along the base of the Rocky Mountain front range, yet from the best information obtainable the territory underlain by coal of workable thickness is not large and the quality is poor, so that much of this part of Montana must necessarily be supplied with coal from the Great Falls field. The Lethbridge field, located north of the international boundary line, is a large coal-producing district, but, as a result of the increased settlement of this part of the British possessions and the duty of 60 cents per ton, much of the output of this field will probably be consumed in Canadian territory, leaving a relatively small amount to be shipped into Montana.

Less than 10 miles from the northern edge of the Sand Coulee basin is located the town of Great Falls, a thriving business center, which has a population of about 18,000. None of its railroad lines are transcontinental, but it is situated on a very important branch connecting the main lines of the Great Northern and Northern Pacific. Railroads extend in four different directions from Great Falls—one southwestward to Helena and Butte; another northeastward to Havre, a small town on the main line of the Great Northern; the Montana and Great Northern northwestward to Shelby Junction; and the Neihart branch of the same road connecting Great Falls with Neihart. The last named is connected by a short branch road leaving it at Gerber station with Stockett and Sand Coulee, two of the larger coal-mining camps of the Sand Coulee basin. In addition to these roads the

Burlington extension from Billings to Great Falls is now under construction. This line will cross the northern edge of the Sage Creek and Otter Creek basins, thus affording shipping facilities for these two undeveloped coal areas. Preliminary surveys have also been made into Great Falls from the south, following Smith River downstream and passing through one of the most promising undeveloped portions of the field.

Another factor to be considered in the general development of this region is the unharnessed water power contained in the falls of Missouri River, located a few miles below the town of Great Falls. At present the Black Eagle Falls, one of the smallest of this series of cataracts and the only one which has been utilized, furnishes power for the large smelters owned by the Boston and Montana Company's flour mills, the city electric-lighting plant, and other minor industries. With the proper utilization of the Rainbow, Crooked, and Big falls, located farther down the river, sufficient power could be generated to supply many more large industrial enterprises. The presence of so large an amount of undeveloped water power within a relatively short distance of the large mining centers Butte and Anaconda makes Great Falls a favorable site for smelting plants.

The Great Falls region was formerly a grazing district and sparsely populated. Small tracts of land were irrigated here and there along the valleys, but with the growth in population and the increased demand for agricultural produce irrigation began to be more generally practiced along the larger streams, resulting eventually in the construction of several large canals by private individuals or small companies organized among the ranchmen. Extensive operations are now being carried on, both by the Government and by private enterprise, to reclaim larger tracts of land along Sun and Teton rivers and the highland lying between these two streams.

Although the Great Falls district is at present not very thickly settled, it is believed that the increasing railroad facilities, the completion of the Government irrigation projects, which will reclaim thousands of acres of fertile farming land, and the almost unparalleled advantages for the development of water power will cause the population to increase rapidly within the next decade. This increase will be attended by an increased demand for coal, both for domestic and steam purposes.

COALS OF CARBON COUNTY, MONT.

By N. H. Darton.

INTRODUCTION.

The area treated in this report comprises about two-thirds of Carbon County, Mont. It lies mainly in the central portion of the county, in and adjoining the valleys of Clark Fork and Rock Creek. The report sets forth the results of examinations made in the autumn of 1906 with a view of determining the extent of the workable coal beds and the structure and stratigraphic relations of the coal-bearing rocks. Previous reports on the coal of the region have consisted of some preliminary notes on the Red Lodge-Bridger mines by Wolff,[a] Weed,[b] Eldridge,[c] and Rowe,[d] and a brief notice of the Bear Creek field published by C. A. Fisher[e] in 1906.

GEOGRAPHY.

The portion of Carbon County treated in this report consists mainly of a hilly country lying between the western slope of Pryor Mountain and the northern side of the Beartooth Mountains. It is traversed from south to north by Clark Fork, a large stream which flows into Yellowstone River. The stream next in size is Rock Creek, which rises in the Beartooth Mountains and empties into Clark Fork northeast of Joliet. Clark Fork flows in a wide valley, into which enter numerous side valleys draining the ridges and plateaus on either side. In this valley are situated three villages of moderate size—Bridger, Fromberg, and Belfry—which are connected by railroad with the Northern Pacific system at Laurel. Rock Creek emerges from a mountain gorge 3 miles above Red Lodge and flows northward in a shallow valley, in which there is another branch of the Northern Pacific. This branch terminates at Red Lodge, a town of about 2,200 inhabitants, sustained largely by the extensive coal-mining operations. Joliet, a small but rapidly growing village, is also situated on Rock Creek.

[a] Wolff, J. E., Rock Creek coal field: Tenth Census, Rept. on Mining, 1875.
[b] Weed, W. H., Coal fields of Montana: Eng. and Min. Jour., vol. 53, 1892, p. 520.
[c] Eldridge, G. H., Bull. U. S. Geol. Survey No. 119, 1894, p. 53.
[d] Rowe, J. P., Montana coal and lignite deposits, Missoula, Mont., 1906.
[e] Bull. U. S. Geol. Survey No. 285, 1906, pp. 269-270.

On the map (Pl. XI) are shown the principal geographic features of the region, including the topography, which is represented by contours with intervals of 200 feet. The map is drawn largely from land-office plats, with various additions and modifications, many of which were obtained from the county map prepared by F. W. Hines. The topography is based mostly on barometric readings connected with points of known elevation at the various railroad stations and with the level line run by the United States Geological Survey from Red Lodge southward. This map will be found much more exact for the areas of coal, where many section corners were located, than for the adjoining region, where no attempt was made to do more than outline the topography.

The most notable topographic features are the deep, wide valley of Clark Fork; the elevated valley of Rock Creek, with its bordering terraces; the western slopes of the Pryor Mountain uplift east of Bridger, and the prominent ridge of limestone and granites on the flank of the Beartooth Mountains south of Red Lodge.

GEOLOGY.

SEDIMENTARY ROCKS.

GENERAL RELATIONS.

The sedimentary rocks outcropping in Carbon County comprise an extensive series of deposits from the pre-Cambrian granites and schists to the Fort Union formation. There is, in general, a regular succession from the "Red Beds" on the flank of Pryor Mountain uplift east of Bridger to the sandstones and shales overlying the uppermost coal measures south of Red Lodge, all having a nearly continuous dip to the southwest. On the northeast side of the high ridge south of Red Lodge these strata are cut off by a profound fault, along which Carboniferous limestone and underlying formations are uplifted with nearly vertical dips. The general stratigraphic succession in the coal-bearing and associated rocks of the area is as follows:

Coal-bearing and associated formations in Carbon County, Mont.

Period.	Formation.	Thickness.	Characteristics.
		Feet.	
Tertiary	Upper barren rocks	2,000	Soft massive sandstones and sandy shales.
Do	Bear Creek-Red Lodge coal-bearing rocks.	100-700	Sandstones and shales with several coal beds.
(?)	Lower barren rocks	6,000-7,000	Sandy shales and soft sandstones with a few thin coal beds.
(?)	Bridger coal bed	3-6	Coal with bone and shale parting.
Cretaceous	Montana shale	2,200+	Mostly dark-gray shale capped by massive buff sandstone.
Do	Colorado shale	1,200	Gray shale with thin hard sandstone near top.
Do	Cloverly sandstone	150	Sandstone and conglomerate with purple and gray clay member near top.

CRETACEOUS SYSTEM.

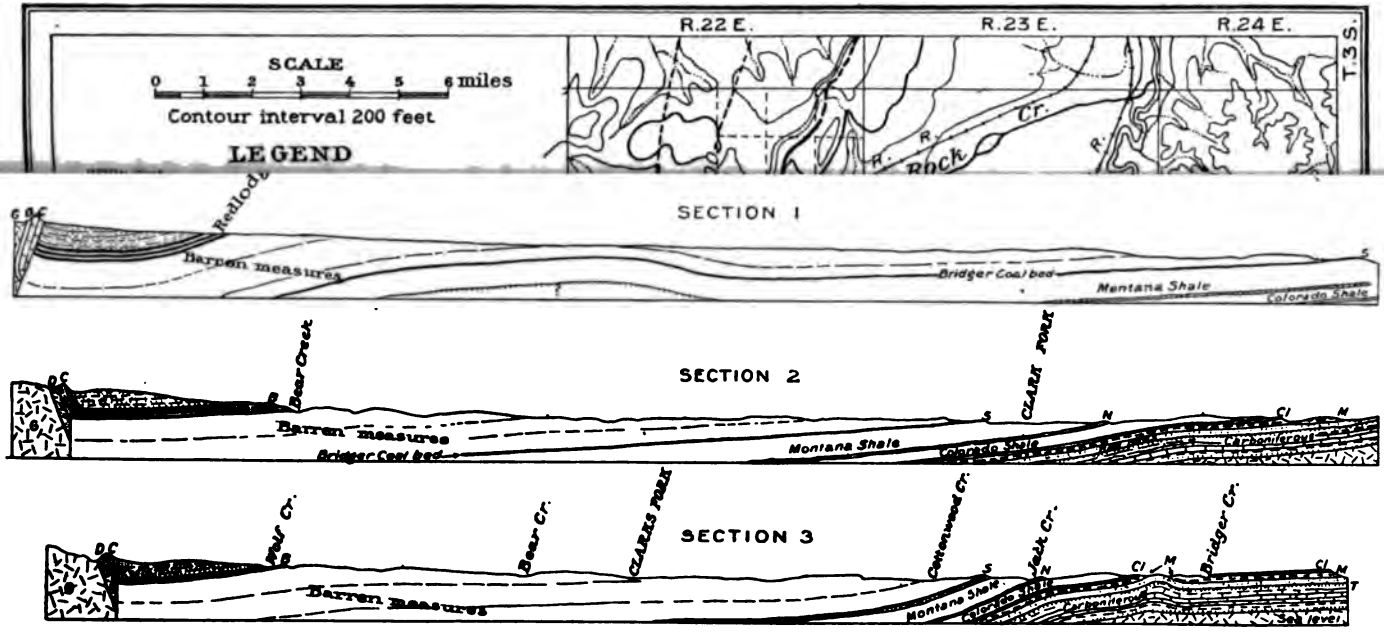
The Cretaceous system is represented in Carbon County by more than 10,000 feet of sedimentary rocks, of which only a small portion near the base are believed to be Lower Cretaceous. The upper limit of the system could not be ascertained and probably a large part of the upper beds in the basin, as well as the Red Lodge–Bear Creek coal-bearing rocks, are of Fort Union (early Eocene) age.

CLOVERLY FORMATION.

The Cloverly formation, consisting mainly of coarse, hard sandstones, outcrops on the slope of the Pryor Mountain uplift in Range 24. Its thickness ranges from 100 to 150 feet and owing to its hardness it gives rise to ridges of considerable prominence through which the streams have cut canyons with precipitous walls. The formation consists of three members. Its lower half is a coarse, massive, hard sandstone, in part conglomerate, especially toward the base. Next above are 50 feet or more of soft shale or clay, of gray and purplish tints, with thin sandstone beds included. At the top are a few feet of gray to buff slabby sandstones, usually weathering to a brownish color. The two lower members are believed to represent the Lakota and Fuson formations of the Black Hills, which are of Lower Cretaceous age, and the upper member to represent the Dakota sandstone or the Kootenai of Canada.

COLORADO FORMATION.

The Cloverly formation is overlain by 1,200 feet or more of gray shale, which outcrops in a wide belt of ridges east of Clark Fork and Jack Creek. These rocks dip gently westward. At the base are about 400 feet of soft shale of dark color; this is succeeded by 150 feet of harder shale, with thin beds of dark-colored, fine-grained sandstone that in the Bighorn uplift is known as the Mowry beds. This member gives rise to ridges of considerable prominence, many of them bearing a few scattered pine trees. It weathers to a light-gray color, and contains large numbers of fish scales, all of which are characteristic features. The Mowry beds are overlain by several hundred feet of light-gray shale with a few thin sandstone layers. This shale is capped by a very characteristic sandstone member, 20 to 50 feet thick, which forms a small but prominent ridge extending along the east side of the valley of Clark Fork to Bridger Creek and thence southeastward along the east side of the valley of Jack Creek. It is a gray, hard sandstone of moderately fine grain, ranging from massive to slabby in bedding. It undoubtedly represents a horizon which is persistent throughout Wyoming and eastern Colorado at or near the top of the Carlile formation, the uppermost member of the



MAP AND SECTIONS OF COAL BASIN IN CARBON COUNTY, MONT.

G, Granite and schist; D, Deadwood formation; C, Carboniferous limestone; T, Tensleep sandstones; M, Morrison and Sundance formations; Cl, Cloverly sandstone; N, Upper sandstone of the Colorado; S, Sandstone in the Montana, under Bridger coal; B, Bear Creek-Redlodge coal measures.

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Benton group. Here and there in the shale a short distance below it occur concretions which contain remains of *Prionocyclus woolgari*, a fossil which also is characteristic of this upper Benton horizon. The sandstone is overlain by shale which appears to merge upward into the shale of the overlying Montana formation (Pierre). As there is no evidence of a break in the stratigraphic succession, probably there exists here a representative of the Niobrara formation, but owing to the lack of fossils and also of the distinctive limy deposits which characterize this formation in other regions, it is not distinguishable in Carbon County. Accordingly, no definite boundary can be drawn between the Colorado and Montana formations.

MONTANA FORMATION.

The wide valley of Clark Fork below the mouth of Bridger Creek is occupied by soft gray shale of the Montana formation, and the outcrop zone of this shale also extends southeastward up the valley of Jack Creek. The shale is 2,000 or more feet thick and is overlain by 200 feet of sandy shale and thin-bedded sandstone, merging upward into a massive sandstone 50 to 60 feet thick, which is tentatively regarded as the top of the formation. This sandstone constitutes a line of ridges and bluffs of moderate prominence in the slopes west of Bridger and Fromberg, north and south of Joliet, and along the south side of Jack Creek valley. It is buff to gray in color, massively bedded, and of moderate hardness. A few fossils were found in the shale, but no organic remains were observed in the sandstone.

On Cottonwood Creek the upper beds of the formation comprise 30 feet of massive sandstone lying upon 100 feet of sandy shale and soft sandstone, 10 feet of harder sandstone, and 50 feet of soft sandstone and sandy shale with sandstone concretions. These rest upon 1,600 feet or more of the shale which underlies Jack Creek valley.

BRIDGER COAL BED.

Overlying the Montana sandstone are a few feet of sandy shale and sandstone containing the Bridger coal bed. The outcrop of this bed extends along the valley or shelf just west of the ridge of Montana sandstone. It passes a short distance west of Bridger, Fromberg, and Joliet, and extends along the ridge lying between Jack and Cottonwood creeks. The coal rarely appears at the surface, but it is opened at a number of mines at intervals through Tps. 4 to 8. The thickness of the coal bed from the vicinity of Bridger to Joliet ranges from 3 feet to 5 feet 8 inches. In the ridge between Jack and Cottonwood creeks the coal rapidly diminishes in thickness, and in an old mine in the northeast corner of T. 8 S., R. 23 E., it is, as reported,

only about 2 feet thick. To the north from Joliet also the coal thins rapidly, but owing to lack of exposures the thickness could not be ascertained. How far westward the Bridger coal extends is not known; to judge by the length of the deposit north and south, however, it may underlie a wide area west of the outcrop zone. The Bridger mine has been worked westward for more than half a mile and the coal shows no signs of diminution in thickness in that distance. In a diamond-drill hole sunk in the center of sec. 24, T. 6 S., R. 22 E., the coaly deposits were entered at a depth of 860 feet and continued to a depth of 980 feet. The log of the boring is as follows:

Log of diamond-drill boring in center of sec. 24, T. 6 S., R. 22 E.

	Ft.	In.
Sand and gravel	23	
Clay, hard	8	
Sandstone and soapstone	43	
Sandstone	14	
Sandstone and soapstone	77	
Sandstone	67	
Sandstone and soapstone	141	
Sandstone	63	
Sandstone and soapstone	76	
Soapstone, part coaly	9	4
Sand and soapstone	6	
Shale, coaly		8
Sandstone, coarse	58	
Sandstone, fine	20	6
Sandstone and soapstone	219	
Sandstone, fine	35	
Shale, in part coaly	18	
Shale, coaly	2	3
Sand, fine	6	9
Soapstone, with 10 inches coaly shale near base	13	
Soapstone, with thin coal and coaly shale	10	
Sandstone	17	
Shale, with thin curly bands	13	8
Soapstone, with 4 feet of sandstone	14	6
Coal	1	8
Sandstone and soapstone	24	
Sandstone, black	7	
Shale, coaly	1	2
Soapstone		6
Coal	1	11
Soapstone	3	
Sandstone	158	6
Soapstone, black	69	
Shale, light brown	4	
Soapstone, black	18	2
Conglomerate?	50	
	1,294	7

A shaft recently sunk at the foot of the sandstone bluff a short distance west of the tipple of the Bridger mine afforded the following section of Bridger coals and associated strata:

Section at Bridger shaft.

	Ft.	In.
Sand	12	
Rock, gray	57	9
Soapstone	6	
Coal	2	
Rock, white		2
Coal		4
Bone		8
Coal		4
Bone	1	10
Coal		6
Bone		4
Coal		11
Soapstone	7	
Coal	1	
Soapstone	2	
Rock, black	4	7
Coal		11
Bone		2
Soapstone		9
Sandstone	5	
Ironstone		8
Soapstone	8	8
Coal		8
Sandstone		2
Coal		2
Soapstone	3	9
Sandstone	2	6
Sandstone	12+	
	130	10

No evidence was obtained as to the age of the Bridger coal, and it may be either Montana or early Laramie.

LOWER BARREN MEASURES.

A wide area lying west of the outcrop of the Bridger coal is occupied by a succession of sandstones and sandy shales several thousand feet thick. These rocks are believed to be, in part, at least, of Laramie age, and they have the features generally associated with that formation. They consist of many extensive bodies of sandstone of gray to buff color, separated by deposits of clay and shale, some of which are carbonaceous and carry thin beds of coal. At the base of the formation, overlying the Bridger coal, is a thick mass of sandstone of considerable hardness, which gives rise to a prominent bluff or ridge. This bluff is especially conspicuous west of Joliet, Fromberg,

and Bridger, and along the divide between Jack and Cottonwood creeks. The sandstone is at least 300 feet thick, including some beds of sandy shale which occur at intervals. The succession is somewhat irregular. At Bridger the coal is overlain by a few feet of sandstone and shale merging upward into 100 feet of gray shale and thin sandstone, over which lies a thick body of sandstone constituting the high ridge. The bore hole that is described on page 179 passes through these beds, but owing to the expression "sandstone and soapstone" used by the driller the character of the rocks is not clear. On Cottonwood Creek the Bridger coal is overlain by 200 feet of heavily bedded, hard, buff sandstone. This is followed by several hundred feet of shales and sandstones, giving place above to a thick mass of hard sandstone which constitutes the high ridge east of Cottonwood Creek. Next above are shales, clays, and thinner-bedded sandstones, followed in turn by another thick sandstone series, which is prominent in high ridges in the center of R. 22, Tps. 5 and 6, and the center of R. 23, T. 8. This sandstone series is followed by a succession of sandstones and shales which extend to the base of the Red Lodge-Bear Creek coal-bearing rocks. The total thickness of the lower barren measures, as approximately determined on several cross-section lines, is at least 5,000 feet, and apparently it approaches 7,000 feet. The dips, however, are low, and the details of stratigraphy are not marked, so that it is difficult to ascertain the thickness precisely. Thin coal beds occur in this formation, but 2 feet appears to be the maximum thickness, and the deposits are not extensive. A 2-foot coal bed has been worked to a small extent in an opening 2¾ miles north of Red Lodge and on the bank of Clark Fork just below the mouth of Dillworth Creek. The latter locality is south of the area shown on the map. Some fossils obtained in the upper beds on Wolf Creek have been determined by T. W. Stanton as follows: *Physa* sp., *Hydrobia* sp., *Viviparus trochiformis* M. and H.?, and *Thaumastus limnæiformis* M. and H.? These are from beds about 600 feet below the top. From higher beds a very short distance below the coal-bearing rocks just east of Bear Creek the following forms were obtained: *Unio priscus* M. and H.?, *Viviparus raynoldsanus* M. and H.?, *Bulinus* sp. and *Goniobasis tenuicarinata* M. and H. Mr. Stanton states that both lots of fossils are suggestive of the Fort Union formation rather than the Laramie, although some of these, as well as other similar species, occur in the Laramie also.

RED LODGE-BEAR CREEK COAL-BEARING ROCKS AND OVERLYING BEDS.

The highest strata in the Carbon County basin consist of 2,000 feet or more of sandstones and shales containing in the lower 600 feet a local development of thick coal beds. Except for the coal the rocks

are similar to those of the barren beds which lie conformably beneath them. They consist largely of sandstones, gray to pale buff in color, and harder in the coal-bearing portion than in the upper part of the series. Shales and clays are interbedded at intervals in bodies from a few inches to 50 feet or more in thickness and they usually contain thin-bedded sandstones. The stratigraphy is variable, and probably there would be great difficulty in tracing individual beds from place to place.

The principal deposits are contained in about 700 feet of strata at Red Lodge, which comprise eleven workable coal beds, as shown by the following section:

Section of coal-bearing beds at Red Lodge.

	Ft.	in.
Slate	4	
Sandstone	10	
Slate	2	
Sandstone	20	
Slate, including 3 inches of bone	14	3
Sandstone	6	
Slate, including 3 inches of bone	18	3
Sandstone	8	
Slate, black	6	
Coal, bed No. 1	11	7
Sandstone	90	3
Shale	3	
Coal, bed No. 1½	4	6
Slate and shale	3	6
Sandstone	18	
Shale	11	
Sandstone	25	
Shale	2	1
Sandstone, gray	6	
Shale	3	
Coal, bed No. 2	6	10
Slate	5	2
Shale, sandy	5	6
Slate	10	
Sandstone	38	7
Slate and sandstone, including 6 inches of bone	8	4
Coal, bed No. 3	11	2
Slate, black	1	
Shale, sandy	20	
Slate, black	4	
Slate, gray	10	
Sandstone	60	
Shale, sandy	19	
Shale, black	1	
Coal, bed No. 4	11	8
Shale	2	6
Sandstone	13	
Shale		2

	Ft.	in.
Shale, sandy	17	
Coal, bed No. 4½	5	4
Slate		1½
Sandstone	40	
Slate, black	2	6
Sandstone	16	
Coal and slate		5
Slate with black dirt	4	6
Coal, bed No. 5	12	4
Shale	12	
Coal, bed No. 6	5	6
Sandstone, slate, and bone	14	
Coal, bed No. 7	2	2
Slate and sandstone	9	
Slate, black	5	
Sandstone	24	6
Slate, blue	10	
Sandstone, gray	6	
Coal, bed No. 8	25	2
Clay	1	
Sandstone, gray	15	
Slate, blue	25	
Bone, dirt, and clay	1	4
Shale, blue	24	
Coal, bed No. 9	11	10
Shale, sandy	4	6
Sandstone	10	
Slate, sandstone, and clay	3	6
Bone		6
	802	6½

The stratigraphy about Red Lodge is well illustrated by the records of diamond-drill borings that have been made in this vicinity. The following section represents a bore hole that was put down in the northern part of Red Lodge, beginning at or near the base of the coal-bearing beds:

Record of bore hole at Red Lodge, in the SW. ¼ NE. ¼ SE. ¼ sec. 27.

	Ft.	in.
Surface	12	
Shale	88	
Bone and coal	2	
Shale	133	
Sandstone	15	
Bone and coal		6
Shale	7	6
Sandstone	40	
Shale	20	
Bone and coal	2	
Shale	30	

	Ft.	in.
Sandstone	18	
Shale	29	
Coal, dirty	10	
Shale	10	
Coal, dirty	1	
Sandstone	25	
Coal, dirty	2	
Shale	55	
Bone and coal	1	
Shale	4	
Sandstone	18	
Coal and bone	10	
Shale	12	
Shale	34	
Coal, dirty	6	
Shale	62	
	647	

As stated on page 180, coal occurs lower down, for there is a small mine on a 2-foot bed 2¾ miles below Red Lodge station, on the west side of Rock Creek, and other thin beds are reported in the interval. The beds dip to the south at angles of 12° to 18° in this portion of the valley, so that several thousand feet of beds appear in a few miles.

The following section represents the strata passed through by a bore hole in the southeastern part of Red Lodge. The rocks penetrated lie in greater part, if not entirely, above coal bed No. 1 of the Red Lodge mines.

Record of bore hole in the SE. ¼ SW. ¼ NE. ¼ sec. 34.

	Ft.	in.
Surface	51	
Shale	118	
Bone and coal		6
Shale	108	6
Sandstone	10	
Shale	42	
Sandstone	10	
Shale	22	
Sandstone	8	
Shale	106	
Sandstone	12	
Shale	109	
Sandstone	18	
Bone and coal	1	
Shale	24	
Sandstone	25	
	665	

The next bore hole begins still farther up in the series overlying the Red Lodge coal beds, but penetrates the underlying coal-bearing

rocks. It is difficult, however, to recognize the individual beds in this record:

Record of bore hole in the SE. ¼ SE. ¼ SE. ¼ sec. 35.

	Ft.	in.
Surface	47	
Sandstone and shale	126	
Shale, hard	42	
Coal and bone	1	
Shale	4	
Sandstone	60	
Coal	1	6
Shale	3	6
Sandstone	14	
Coal, dirty	4	
Sandstone	12	
Shale	45	
Sandstone	44	
Coal, dirty	8	
Sandstone	53	
Coal and bone	1	6
Shale	101	6
Coal and bone	10	
Shale	99	
Coal, good	8	
Sandstone	5	
Shale	28	
Coal, good	3	
Shale	2	
Sandstone and shale	109	
Shale	7	
Coal	1	
Shale	3	
Coal, dirty	2	
Shale	5	
Coal, dirty	5	
Sandstone	5	
Shale	29	
Coal, dirty	5	
Shale	16	
Sandstone	28	
Shale	23	
Coal		6
Sandstone	1	6
Bone and coal	2	
Shale	5	
Sandstone and shale	68	
Coal		6
Sandstone	3	6
Shale	22	
Sandstone	11	
Shale	6	
Coal and shale	4	
Shale	55	
	1,140	

The coal measures of Red Lodge strike nearly due east across the divide lying between the head of Rock Creek and the northerly forks of Bear Creek. They are thickly covered by gravel on this wide, flat-topped divide, but appear again extensively in the Bear Creek basin. There is some variation in thickness and succession of the coal and inclosing beds, but the salient features persist for some distance. The dip decreases to 5° and less and its direction gradually changes more to the west. The succession in the vicinity of the Bear Creek mines is shown in the following section:

Section of coal measures on Bear Creek.

		Ft.	in.
Coal, No. 1, clean		6	
Sandstone with thin coal beds and fire clay		141	
Coal, No. 2, clean		6	6
Sandstone, mostly coarse		102	
Shale		6	
Coal	No. 3	8	5
Fire clay	No. 3		10
Coal	No. 3	2	
Sandstone, very hard		45	
Coal	No. 4	2	2
Clay	No. 4		2
Coal	No. 4	2	2
Clay		75	
Coal, No. 5, clean		4	6
Sandstone		40	
Coal, No. 6, clean		4	
Sandstone		80	
Coal, No. 7, clean		10	
Sandstone and shale		70	
Coal, No. 8, clean		5	
		610	9

The coal-bearing formation has a thickness of about 600 feet, in which there are about 50 feet of coal. There are eight principal beds, but above and below these are additional thin beds which have no value at the present time.

The coal beds are exposed at various places near the town of Bear Creek and present but little variation in their character and relations. To the south, however, they rapidly become thinner and more impure, so that in the vicinity of Grove Creek, where they pass under a thick mantle of alluvial wash, they are few in number and of greatly diminished thickness. In the next township south they are too thin to be workable under present conditions. In Foster Gulch, a mile and a half southwest of Bear Creek post-office, bed No. 3 is 8 feet thick, and consists entirely of clean coal of fine quality.

Fossils occur very abundantly in the roof of No. 3 coal bed in the Bear Creek mines. They comprise the following species, determined by Mr. Stanton: *Unio priscus* M. and H.?, *Sphærium formosum* M. and

H.?, and *Goniobasis tenuicarinata* M. and H. These forms suggest that the strata may be of Fort Union age, but they do not afford conclusive evidence. J. P. Rowe has obtained fossil leaves from sandstones separating the coal beds in the Red Lodge field, which he states are of Fort Union age.[a]

IGNEOUS ROCKS.

The coal-bearing rocks in the Red Lodge–Bear Creek field are traversed by several dikes of dark-colored igneous rock occupying vertical fissures. They average a foot in thickness and extend west-northwestward, rudely parallel to the course of the great fault which brings up the Madison limestone 2 to 3 miles farther southwest. Their contact relations are clearly exposed at some points, and they appear to have caused but little alteration in the sandstones and shales which they traverse. Their influence on the coal was not ascertained, but presumably they harden it and decrease the amount of volatile constituents for a short distance. On microscopic examination by Albert Johannsen the rock was found to be a camptonite, consisting of augite crystals in a groundmass of plagioclase, magnetite grains, and some apatite. It is of medium dark-green color and has a mottled appearance, due to the small scattered prismatic black crystals of augite, rarely 1 mm. in length, in an aphanitic decomposed groundmass. This groundmass consists of 50 per cent of minute crystals of augite, generally in laths and usually altered, 5 per cent of magnetite, and a small amount of apatite scattered in an aggregate of plagioclase. The minerals are greatly altered, some of the augite being changed to greenish-yellow serpentine.

STRUCTURE.

The coal field treated in this report is a monocline extending southwestward from the western slope of the Pryor Mountain uplift. On the southwest it is cut off by a fault having a throw of many thousand feet, which brings to the surface granite and some overlying Paleozoic rocks that constitute the Beartooth Mountains. In the eastern part of the area the dips are relatively steep, averaging 10°, but to the west and southwest they diminish to less than half that amount, and in some areas the strata are horizontal. A local anticline appears on Rock Creek, near Roberts, and extends some distance southeastward, as shown in section 1 on the map. In the coal mines west of Bridger the dip is approximately 6°; west of Fromberg and near Joliet it ranges from 4° to 5°. The structure of the Bridger coal is indicated by contour lines on the map. In the region about Belfry very low dips prevail and the strata are nearly horizontal along the lower portions of Wolf and Grove creeks. In the coal mines at Bear Creek the dips are to the southwest at low angles, the amount being 3½° in the

[a] Montana coal and lignite deposits: Bull. Univ. Montana No. 37, 1906, p. 24.

Bear Creek Company's mine and 9° at the Nelson mine. At the mine in the west-central part of section 8, a mile and a half southwest of Bear Creek, the direction is S. 18° W. and the angle 4°. At Red Lodge the coal beds dip toward the south at an angle of 18° (see section on Pl. XI, p. 176), but farther south this steep dip rapidly diminishes, the structure grading into a very shallow syncline in which the strata are horizontal for some distance and then apparently slightly upturned near the fault at the foot of the mountains. The strata dip at very low angles throughout T. 8 S., R. 20 E., but are not upturned adjacent to the fault except in the immediate vicinity of Rock Creek. North of Red Lodge the steep dips diminish gradually. Two miles north the rocks dip nearly due south at an angle of 12°. Six miles farther north they pass over a gentle anticline and for half a mile dip northward at an angle of 10°. Near Roberts they are horizontal, and farther northeast they are inclined at low angles to the southwest.

Faults are rare and only two were observed in addition to the great fault south of Red Lodge. One traverses the Bridger coal bed and adjoining strata southwest of Fromberg. It trends northeast and southwest and has a downthrow of several hundred feet on the north side. This causes an offset of nearly a mile and a half in the outcrop of the coal bed in the southeast corner of T. 5 S., R. 22 E.

COAL RESOURCES.

RED LODGE.

The mine at Red Lodge is owned by the Northwestern Improvement Company. It is in the bluff on the east side of Rock Creek in the eastern portion of the village. The first developments were made in 1887, three years after coal was discovered. The original operations were small, but in 1889 they had increased to 6,000 tons a year. There are ten coal beds at this place, and their aggregate workable thickness is about 85 feet, including thin partings in some of the beds. The sections of the principal beds are as follows:

Sections of coal beds at Red Lodge.

COAL BED NO. 1.

	Ft.	in.
Shale.		
Coal		4
Shale	2	
Bone and coal		7
Coal		6
Bone		4
Coal		4
Shale and coal	1	
Coal	2	6
Bone		4
Coal	3	6
Shale, black		2
Sandstone.		
	11	7

COAL BED NO. 1½.

	Ft.	in.
Coal, with thin parting	1	
Coal and shale		2
Coal	1	
Shale		¼
Coal		8
Bone		¼
Coal		10
Parting, thin		
Coal		4
Shale		½
Coal		5
Shale.		
	4	6

Sections of coal beds at Red Lodge—Continued.

COAL BED NO. 2.

	Ft.	in.
Shale.		
Bone		2
Coal		6
Bone and coal		4
Coal, with thin partings above center	3	4
Shale		3
Coal, with shale parting below center	2	3
Shale.		
	6	10

COAL BED NO. 3.

	Ft.	in.
Bone		6
Shale		3
Bone and coal	1	
Shale		1
Coal		10
Shale		1
Coal	1	4
Shale		1
Coal	1	2
Shale		2
Coal	2	
Shale		6
Coal		10
Shale		1
Coal		3
Shale		4
Coal	1	6
Shale	1	
Sandstone.		
	12	

COAL BED NO. 4.

	Ft.	in.
Shale	1	
Coal, with four thin partings	2	7
Coal and dirt		6
Coal	2	9
Bone		3
Coal		5
Shale		1
Coal, with three thin partings	4	1
Shale.		
	11	8

COAL BED NO. 4½.

	Ft.	in.
Sandstone.		
Coal	2	
Shale		1
Coal		5
Shale		2
Coal, much sulphur		7
"Sulphur"		1
Coal	1	2
Bone		2
Coal		2
Dirt		6
Shale.		
	5	4

COAL BED NO. 5.

	Ft.	in.
Shale.		
Bone		2
Coal	3	4
Shale		1
Coal, with one thin parting	1	10
Dirt		5
Shale		6
Coal	3	
Bone		1
Coal, with two thin partings	2	11
Sandstone.		
	12	4

COAL BED NO. 6.

	Ft.	in.
Sandstone.		
Coal, with two thin partings	5	6
Bone		4
Shale.		
	5	10

COAL BED NO. 8.

	Ft.	in.
Bone		6
Coal		5
Shale		1
Coal		3
Shale		1
Coal, with one thin parting	1	1
Clay	3	6
Coal	1	
Shale		1
Coal	1	
Clay	1	10
Coal, with three thin partings	3	
Bone		1
Coal	1	4
Shale		6
Sandstone	1	4
Coal	3	
Bone		2
Coal	1	
Bone		1
Coal		10
Coal and dirt		5
Coal		4
Shale		1
Coal		6
Clay		4
Coal	2	6
Clay.		
	25	4

COAL BED NO. 9.

	Ft.	in.
Shale, black.		
Coal	1	
Coal and shale		10
Coal		8
Bone		5
Coal	4	
Clay		6
Sandy shale	1	6
Coal, with two 2-inch partings	1	9
Sandy shale.		
	10	8

Beds Nos. 1, 1½, 2, 4, 5, and 6 are worked, but the most extensive operations are in bed 4. One level about half a mile down the slope runs eastward from the main slope more than 7,500 feet and has 110 rooms. There are numerous other levels both east and west. In bed No. 1 there are 10 rooms, in bed No. 1½ 31 rooms, and in bed No. 2 four east and three west levels, but some are not being worked. The mine is worked and lighted by electricity, generated by a plant erected by the company. It has a steel tipple with a capacity of 3,000 tons a day, revolving and shaking screens, picking tables, gravity box-car loader, 8 spiral separators, and a 600-ton Luhrig washer. About 500 miners and 100 outside men are employed. The production in ten months ending October, 1906, was 356,573 short tons in 209 working days.

BEAR CREEK FIELD.

The coal in the Bear Creek field has been known for nearly twenty years, but no mining was done until 1900, when the Montana Fuel and Iron Company opened a small mine and hauled its product to Red Lodge for shipment. The annual production was reported as 6,000 tons, at $3.30 a ton. During the last few years the construction of a railroad to the field has led to the development of several mines, and four companies now have extensive holdings. They are the Bear Creek Coal Company, the Montana Fuel and Iron Company, the Anaconda (Amalgamated) Company, and the Northwestern Improvement Company, the last being the owner of the Red Lodge mine. During 1906 the Yellowstone Park Railroad was completed from Bridger to the Bear Creek mines, so that the coal now has an outlet by way of the branch of the Northern Pacific Railway from Bridger.

The Bear Creek Company controls an area of approximately 10,000 acres. Its mines are in the NE. ¼ sec. 6, T. 8 S., R. 21 E., about a mile west of the new town of Bear Creek. The principal openings are in bed No. 2, having a thickness of 6½ feet, and bed No. 3, which yields about 10 feet of coal. The dip is to the southwest, at an angle of 3½°, and the workings are mostly toward the north, so that the mines drain easily. There is, however, but little water in them. In the autumn of 1906 the main gangway in bed No. 2 was 600 feet long, in bed No. 3, 1,000 feet, and in bed No. 4, 200 feet. The coal is hauled in the mines by electricity, which is generated in a large power house recently erected. It is reported that in September and October, 1906, about 3,000 tons were produced with a force of 75 miners and 8 outside men. With the completion of the tipple that was in course of erection in the latter part of 1906, a large increase in the production was expected.

The mine of the Montana Fuel and Iron Company is in the NW. ¼ sec. 6, half a mile west, or farther up the valley than the mines of the Bear Creek Company. It is on bed No. 2 and its main gangway runs

northward under the hillside. The coal bed is 6½ feet thick, with a 3-inch layer of bone 6 inches below the top. The roof is hard clay shale. A spur of the railroad extends to the mine, which is equipped with a tipple and other facilities for handling the coal. From 25 to 40 men are working in the mine.

A mine has recently been begun on the McCarthy properties on a northern prong of Bear Creek, in the NW. ¼ sec. 31 and the S. ½ sec. 36. The opening is in bed No. 2, which yields 6 feet or more of clean coal.

The following measurements of the coal beds in the Bear Creek mines were made by J. P. Rowe in the summer of 1906:

Sections of coal beds in Bear Creek mines.

COAL BED NO. 3.

Shale.	Ft.	in.
Coal	1	5
Parting, thin.		
Coal	1	4
Bone		2½
Coal	2	7½
Clay		8
Coal	1	7½
Fire clay.		
	7	10½

COAL BED NO. 4.

Sandstone.	Ft.	in.
Coal, dirty		2
Coal	1	9½
Bone		3½
Coal	1	5½
Clay, 4 inches, on sandstone.		
	3	8½

COAL BED NO. 5.

[150 feet in from mouth of entry.]

Clay.	Ft.	in.
Coal	3	5
Clay		7
Coal		10
Clay.		
	4	10

NELSON MINE.

The Nelson mine is a small opening on the south side of Taggart Gulch, in the SE. ¼ sec. 20, T. 8 S., R. 21 E., 3 miles south of Bear Creek. It is worked entirely by hand, and furnishes a small but steady product which is hauled to neighboring ranches. The coal is slightly more than 4 feet thick, with a few inches of clay parting in the middle. The dip at the Nelson mine is S. 55° W. at an angle of 9°.

Section at Nelson mine, 3 miles south of Bear Creek.

	Ft.	in.
Coal	1	
Clay	2	6
Coal	2	
Clay		3–8
Coal	2	6

BRIDGER MINES.

The mines of the Bridger Coal and Improvement Company are in the sandstone ridge a mile northwest of Bridger, the opening being in the SW. ¼ SW. ¼ sec. 17. The mines are connected by a long spur with the branch of the Northern Pacific Railway. They were opened in 1897, and the main entry now has a length of about 3,000 feet. The beds dip to the southwest at an angle of 6°, and the main entry is down the slope to the west-southwest. The coal bed is from 4½ to 5 feet thick, and consists of about 2½ feet of coal at the base and a foot or more at the top, separated by a parting of shale, clay, and bone which averages 8 inches, but in places increases to more than 2 feet in

thickness. The lower coal is generally the better. In the southwestern workings the upper coal is 21 inches thick, the parting 12 inches, and the bottom bench 2 feet, but the latter is partly bony. About 80 miners and 25 outside men are employed, and the product is about 150 tons a day. In the first ten months of 1906, with 220 working days, the output was 35,000 short tons. The coal is worked by the long-wall system and undercut by eight electric link-belt machines. The coal is hoisted up the incline and carried on a trolley line nearly three-fourths of a mile to the tipple. About 20 per cent is screened out and the screenings are used for fuel for an extensive electric plant operated by the company. This plant has two dynamos which run a 250-horsepower hoist, trolley line, pumps, a 30-horsepower fan, the town lights, and a 60-horsepower pump. The tipple is equipped with all conveniences, including a steam box-car loader.

McCARTHY MINE.

The McCarthy mine is in section 19, a mile south of west from Fromberg, and the coal is hauled in wagons to the railroad at that place. The section of the coal bed is as follows:

Section of Bridger coal bed at McCarthy mine, near Fromberg.

Bone and coal.	Ft.	in.
Coal	2	
Shale		2
Coal	2	10
	5	

The parting changes to coal in places. The beds dip gently south of west and the main gangway runs northward, so that there is a slight descent to its mouth. Twelve miners are employed and three outside men dump the coal over screens into wagons. In the first ten months of 1906 the mine worked 250 days and produced 9,000 tons of coal.

GEBO MINE.

The Gebo mine is a short distance west of Gebo, and is connected with the branch line of the Northern Pacific Railway by a spur from Fromberg. The section of the coal bed is as follows:

Section of Bridger coal bed at Gebo mine.

Shale.	Ft.	in.
Coal	2	3
Bone		2
Coal	3	3
	5	8

The beds dip 4° to 5° SW. and the workings are so arranged as to afford gravity drainage. The present extent of the workings is about 900 feet. Forty-five men are employed in the mine and twelve outside, and the product is about 200 tons a day. The tipple, which is of steel, is nearly a mile from the opening. Electric power is used for tram, hoist, drilling, and ventilation.

JOLIET.

The Bergen mine, belonging to the Joliet Coal and Fuel Company, is in the NE. ¼ NW. ¼ sec. 35, T. 4 S., R. 22 E., 2½ miles west of south of Joliet. The section of the coal bed in this mine is as follows:

Section of Bridger coal bed at Bergen mine.

	Ft.	In.
Sandstone.		
Coal and bone	1	2
Shale		8
Coal	1	
Bone		6
Coal	2	2
	5	6

The bone and shale afford a very satisfactory roof. The beds dip southwest, and the main entry, which runs westward, is about 600 feet long. A small force is employed, and the output is from 40 to 50 tons a day in winter and 15 tons in summer. Most of the coal is hauled by wagon to Joliet and to Wilsey station, but a small amount is sold at the mine for $2.50 a ton.

Two other small mines a mile and a half south of Joliet are worked intermittently. They have about 2 feet of coal at base, which is said to contain 26 to 27 per cent of ash. Several years ago a mine was worked on the south bank of Rock Creek, a mile above Joliet, but it is now fallen shut and a section could not be obtained. Doubtless the coal bed is similar to that in the mines above described. A small mine was once operated a mile north of Joliet in which the Bridger bed is about 4 feet thick, but not of satisfactory quality.

CARBONADO.

Several years ago a large shaft was sunk at Carbonado station to reach the Bridger coal bed. A preliminary drill hole was bored, which gave promise of a thick bed, but in the shaft the coal has a thickness of 4 feet with a parting, and occurs at a depth of about 980 feet. The enterprise belonged to the late Marcus Daly and was equipped for extensive workings. A very large amount of water was encountered, and as the bed was not satisfactory the project was abandoned.

CHEMICAL COMPOSITION OF THE COAL.

The composition of the Red Lodge, Bear Creek, and Bridger coals is shown by the following analyses made at the Geological Survey fuel-testing plant at St. Louis. This table shows the analysis of each sample as received and also after air drying. The former generally contains more moisture than the commercial coal, and the latter

probably shows less. For purposes of comparison, however, the analysis of the air-dried sample should be used. The samples for analysis were obtained by making a cut from roof to floor of the coal bed, excluding partings.

Analyses of coal samples from Carbon County, Mont.

	Red Lodge.						
Laboratory No.	3590.	3592.	3588.	3595.	3591.	3593.	3594.
Analysis of sample as received:							
Prox. Moisture	11.69	14.07	11.26	11.33	11.22	10.38	10.55
Prox. Volatile matter	36.14	33.46	34.08	34.22	36.43	35.98	36.39
Prox. Fixed carbon	40.19	42.51	43.26	44.04	45.38	40.62	43.02
Prox. Ash	11.98	9.96	11.40	10.41	6.97	13.02	10.04
Ult. Sulphur	1.05	2.05	1.14	1.59	.83	1.89	2.23
Ult. Hydrogen	5.26	.....	.....	.....	.....	.....	.....
Ult. Carbon	55.46	.....	.....	.....	.....	.....	.....
Ult. Nitrogen	1.20	.....	.....	.....	.....	.....	.....
Ult. Oxygen	25.05	.....	.....	.....	.....	.....	.....
Calorific value determined:							
Calories	5,437	.....	.....	.....	.....	.....	.....
British thermal units	9,787	.....	.....	.....	.....	.....	.....
Loss of moisture on air drying	4.70	5.60	4.00	4.40	4.00	4.20	3.90
Analysis of air-dried sample:							
Prox. Moisture	7.34	8.97	7.57	7.25	7.52	6.45	6.92
Prox. Volatile matter	37.92	35.45	35.50	35.80	37.94	37.56	37.87
Prox. Fixed carbon	42.17	45.03	45.06	46.06	47.28	42.40	44.77
Prox. Ash	12.57	10.55	11.87	10.89	7.26	13.59	10.44
Ult. Sulphur	1.10	2.17	1.18	1.66	.86	1.97	2.32
Ult. Hydrogen	4.97	.....	.....	.....	.....	.....	.....
Ult. Carbon	58.20	.....	.....	.....	.....	.....	.....
Ult. Nitrogen	1.26	.....	.....	.....	.....	.....	.....
Ult. Oxygen	21.90	.....	.....	.....	.....	.....	.....
Calorific value determined:							
Calories	5,705	.....	.....	.....	.....	.....	.....
British thermal units	10,269	.....	.....	.....	.....	.....	.....

	Bear Creek.			Bridger field.		
Laboratory No.	3620.	4007.	4008.	3955.	3956.	3954.
Analysis of sample as received:						
Prox. Moisture	10.05	8.97	9.60	8.47	8.70	8.93
Prox. Volatile matter	37.22	36.11	36.88	31.47	34.03	33.43
Prox. Fixed carbon	46.71	43.18	47.10	41.88	49.07	46.92
Prox. Ash	6.02	11.74	6.42	18.18	8.20	10.72
Ult. Sulphur	1.44	3.02	2.35	.84	.63	.61
Ult. Hydrogen	5.41	.....	.....	.....	.....	.....
Ult. Carbon	59.64	.....	.....	.....	.....	.....
Ult. Nitrogen	1.40	.....	.....	.....	.....	.....
Ult. Oxygen	26.09	.....	.....	.....	.....	.....
Calorific value determined:						
Calories	6,219	.....	.....	.....	.....	.....
British thermal units	11,194	.....	.....	.....	.....	.....
Loss of moisture on air drying	2.00	2.10	2.60	3.20	3.10	3.60
Analysis of air-dried sample:						
Prox. Moisture	8.21	7.02	7.19	5.44	5.78	5.53
Prox. Volatile matter	37.98	36.88	37.86	32.51	35.12	34.68
Prox. Fixed carbon	47.67	44.11	48.36	43.27	50.64	48.67
Prox. Ash	6.14	11.99	6.59	18.78	8.46	11.12
Ult. Sulphur	1.47	3.08	2.41	.87	.65	.63
Ult. Hydrogen	5.30	.....	.....	.....	.....	.....
Ult. Carbon	60.86	.....	.....	.....	.....	.....
Ult. Nitrogen	1.43	.....	.....	.....	.....	.....
Ult. Oxygen	24.80	.....	.....	.....	.....	.....
Calorific value determined:						
Calories	6,346	.....	.....	.....	.....	.....
British thermal units	11,422	.....	.....	.....	.....	.....

Sample with laboratory No. 3590 was from bed No. 1; 3592, bed No 1½; 3588, bed No. 2; 3595 and 3591, bed No. 4; 3593, bed No. 5; 3594, bed No. 6; 3620, bed No. 2, 1 mile northwest of Bear Creek; 4007, from Foster Gulch a mile farther west; 4008, from Taggart Gulch; 3955 and 3956, west of Bridger; and 3954, a mile southwest of Fromberg.

THE COAL FIELDS OF PARTS OF DAWSON, ROSEBUD, AND CUSTER COUNTIES, MONT.

By A. G. LEONARD.

LOCATION AND EXTENT.

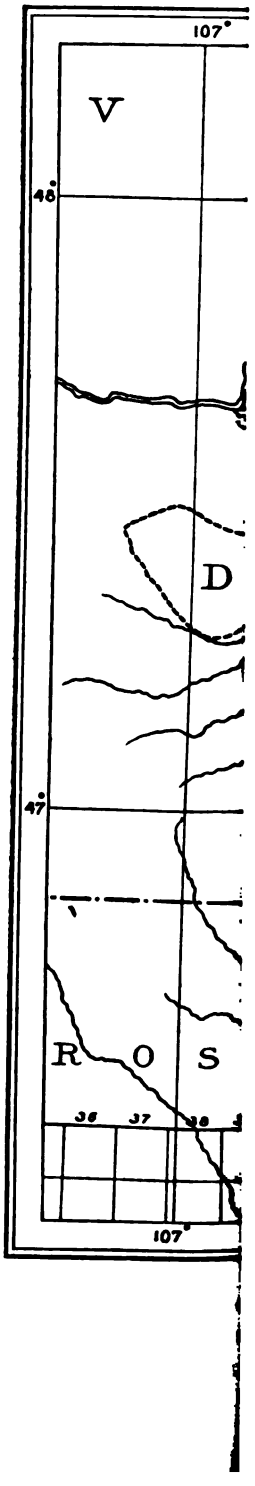
The Dawson-Rosebud-Custer County coal district forms part of a larger area which includes the greater portion of eastern Montana, most of the western half of North Dakota, and the adjoining parts of South Dakota and Wyoming; it also extends northward into Canada. Coal is known to occur as far west as Bighorn and Musselshell rivers in Montana and the Bighorn Mountains in Wyoming. In South Dakota the lignite is mostly confined to Butte County, in the northwest corner. Farther west in Wyoming the field extends southward in a tonguelike area between the Black Hills and Bighorn Mountains for more than 150 miles to North Platte River and includes parts of Sheridan, Johnson, Crook, Weston, and Converse counties. The area measures about 350 miles in an east-west direction, and at its widest part a greater distance in a north-south direction. It contains approximately 100,000 square miles and is equal to the area of Colorado or more than twice the area of New York State.

The coal of this great field ranges in quality from brown, woody lignite in the eastern part to black, shining subbituminous[a] coal in the western part. The transition from one to the other occurs near the eastern boundary of Montana, so in a general way the lignites are confined to North and South Dakota and the subbituminous coal to Montana and Wyoming.

That portion of the field which is described in this brief preliminary report includes parts of Dawson, Rosebud, and Custer counties, Mont. Custer County occupies the southeast corner of the State; Rosebud County is immediately west of it; and Dawson County, which borders the other two on the north, lies almost wholly between Yellowstone and Missouri rivers. The field work was confined largely to Dawson County, but included the portion of Custer and Rosebud counties lying north and west of Yellowstone River and a small area south of the river in the vicinity of Miles. The route traversed by the field party is shown on Pl. XII.

[a] The name subbituminous has recently been adopted by the United States Geological Survey for the class of coal above the brown lignites and below the bituminous coals—the class generally called "black lignite."

U. S. GEOLOGICAL SURVI



UNIT

SURFACE FEATURES.

The greater part of the region may be characterized as a rolling plain, although there are extensive tracts of exceedingly rough badlands along Missouri and Yellowstone rivers and many of their tributaries. One of the largest of these badlands areas includes the 22 townships of Custer and Rosebud counties lying north of Yellowstone River. Another similar area, which is almost too rough to be traversed, occupies a broad belt on the south side of Missouri River, west of the mouth of Big Dry Creek, in northwestern Dawson County. Aside from these and similar smaller tracts the region as a whole is a wide-stretching, rolling prairie.

Big Sheep Mountain and Little Sheep Mountain, in southern Dawson County, are the highest points in the divide separating the drainage basin of the Missouri from that of the Yellowstone. These so-called "mountains," with bare clay sides, rise abruptly 150 feet above the gentle, grass-covered slopes of the divide and form a conspicuous landmark, which may be seen from a great distance. Cedar, Cherry, and Custer creeks, tributaries of the Yellowstone, are rapidly extending their valleys by headward erosion and encroaching on the upper branches of Redwater River and other tributaries of the Missouri.

Southeast of Miles, 5 or 6 miles back from the river, the Pine Hills rise 700 feet above the Yellowstone. The elevation of the divide between the Yellowstone and the Missouri is likewise about 700 feet above those streams. The broad valleys of these two rivers form natural highways followed by the railroads and wagon roads. The country lying between them is well drained by numerous streams, all but the larger of which run dry during the summer. The two most important are Big Dry and Redwater creeks, both tributaries of the Missouri. The creeks flowing into the Yellowstone are much shorter and include Sunday, Custer, Cherry, Cedar, and Bad Route creeks. Little Dry and Timber creeks are important tributaries of Big Dry Creek. (See Pl. XII.)

STRATIGRAPHY.

PIERRE SHALE.

The lowest member of the Montana group is the Pierre shale, which underlies the coal-bearing beds and appears at the surface at a number of localities within this field. One of these is on the Yellowstone, 12 miles above Glendive, at the mouth of Cedar Creek and extending downstream as far as Iron Bluff. The shale is brought to the surface by an anticlinal fold and the dipping beds on the southwestern flank of the fold can be seen on both sides of the river. The dip is 20° S. 52° W. and the strike is N. 38° W. The

dark-gray jointed shale contains numerous concretions of impure limestone, many of them rich in fossils. The following forms were identified by T. W. Stanton:

Avicula nebrascana M. and H.
Avicula linguæformis E. and S.
Inoceramus sagensis Owen.
Inoceramus cripsi var. barabini Morton.
Modiola meeki E. and S.
Veniella subtumida M. and H.
Callista deweyi M. and H.
Anchura americana E. and S.
Haminea occidentalis M. and H.
Pyrifusus newberryi M. and H.
Lunatia concinna M. and H.
Scaphites nodosus var. quadrangularis M. and H.
Scaphites nodosus Owen vars. brevis and plenus.
Limopsis parvula M. and H.
Yoldia evansi M. and H.
Lucina subundata M. and H.
Protocardia subquadrata E. and S.
Dentalium gracile M. and H.
Vanikoro ambigua M. and H.
Margarita nebrascensis M. and H.
Fasciolaria (Piestocheilus) culbertsoni M. and H.
Baculites ovatus Say.
Nautilus dekayi Norton.
Chlamys nebrascensis M. and H.

Along the extreme eastern edge of Custer County and continuing across the line into North Dakota is another area of Pierre shale which forms a belt extending many miles north and south on either side of the boundary. This shale also contains many calcareous concretions filled with fossils. The beds are well exposed on Little Beaver Creek, about 6 miles above its mouth, in secs. 23 and 24, T. 132 N., R. 107 W., Bowman County, N. Dak. From this locality the following fossils were collected:

Ostrea pellucida M. and H.
Avicula linguæformis E. and S.
Inoceramus cripsi var. barabini Morton.
Chlamys nebrascensis M. and H.
Yoldia evansi M. and H.
Nucula cancellata M. and H.
Lucina occidentalis Morton.
Protocardia subquadrata E. and S.
Callista deweyi M. and H.
Lunatia.
Anisomyon patelliformis M. and H.
Margarita nebrascensis M. and H.
Fasciolaria? (Cryptorhytis) flexicostata M. and H.
Pyrifusus.
Haminea? occidentalis M. and H.
Scaphites nodosus Owen var. brevis and plenus.
Nautilus dekayi Morton.

It is probable that the anticline so well shown on the Yellowstone has affected a wide area, since ammonites and other marine fossils are reported to occur on Cedar Creek 8 or 10 miles above its mouth and also many miles to the southeast on Cabin Creek. The Pierre shale thus extends a considerable distance toward the area on Little Beaver Creek, and the anticline, if continued in the direction of the strike of the beds (S. 38° E.), would include the latter area. The

Pierre shale exposed at the two localities is therefore probably brought to the surface by the same uplift and the two areas of outcrop are perhaps continuous.

There are extensive outcrops of the Pierre shale in northwestern Dawson County, where the beds are exposed along the Missouri and its tributaries. Southeast of Glasgow, at the mouth of Big Dry Creek, the shale in the river bluffs rises 200 feet above water level. No fossil-bearing calcareous concretions were observed at this point, although search was made for them, but otherwise the beds show all the characteristics of the Pierre. The shale was also observed on Hell Creek, a southern tributary of the Missouri, which empties into the river about 20 miles above the mouth of Big Dry Creek. At this place the shale has a thickness of at least 150 feet above creek level and contains calcareous concretions, with numerous fossils, among which ammonites and baculites are most common.

In the extreme southeast corner of Custer County, as the result of the Black Hills uplift, the Pierre shale outcrops over an area of considerable extent, overlying the Benton and Niobrara formations, which also appear at the surface.

FOX HILLS FORMATION.

The Fox Hills formation, lying above the Pierre, is the uppermost formation of the Montana group and the most recent of the marine Cretaceous strata. The relation of these beds to the Pierre below and the overlying rocks is well shown on Hell Creek, a tributary of the Missouri in northwestern Dawson County. In the section exposed along the sides of the deep valley of this creek, lying above the dark-gray shale with its concretions filled with Pierre fossils, are 100 feet of clay and sandstone that are believed to belong to the Fox Hills. The formation is composed largely of light-gray to buff, more or less sandy clay, with some layers of nearly pure sand. About 8 feet below the top there is a rather persistent bed of fine-grained yellow sandstone with a thickness of 11 feet. The beds as a whole are lighter in color and more sandy than the Pierre shale. Mr. Barnum Brown, in conversation with the writer, reports that they contain few fossils, but those that have been found were identified as probably belonging to the Fox Hills.

In the Glendive region there are no beds above the marine Pierre that correspond to the supposed Fox Hills clay and sandstones of Hell Creek. In fact, the line of contact between the Pierre and the overlying dinosaur-bearing beds, while not discordant so far as structure is concerned, may possibly represent a time break in which most of the upper fresh- and brackish-water beds of the Cretaceous are wanting.

DINOSAUR-BEARING BEDS.

Heretofore all the beds above the marine Pierre shale have been regarded as belonging to a single formation which carries the lignite and subbituminous coal beds of this field These rocks have been called, at various times, "Laramie" and "Fort Union," on the supposition that they composed but a single formation. The work of the last year, however, has shown that at Glendive the rocks above the Pierre shale apparently comprise two formations which seem to be reasonably separate and distinct, and that the upper formation only carries beds of lignite. The lower beds are well exposed between Glendive and Iron Bluff, where the following section was measured:

Section of rocks at Iron Bluff and vicinity.

	Feet.
8. Coal bed, burned, but probably 6 feet thick.	
7. Shale with a few thin beds of sandstone; abundant collection of fossil plants in sandstone bed 20 feet from base	150
6. Sandstone, massive, gray	40
5. Shale and sandstone; a few fossil plants at base	160
4. Sandstone, white, massive; most prominent stratum in the region	35
3. Sandstone, brown, fossil leaves in bottom part; forms summit of Iron Bluff	75
2. Shale and sandstone; fossil leaves in upper 20 feet	75
1. Shale, dark, Pierre, with limestone concretions containing abundant marine fossils; exposed to river level	100
	635

As noted in the section, fossil leaves were found at three horizons. The uppermost location (No. 7) is about 400 feet above the Pierre, and from this was obtained a fair collection of fossil plants which Knowlton regards as representing, approximately, the base of the Fort Union formation. The fossils obtained 75 to 100 feet above the Pierre (Nos. 2 and 3), as well as those from slightly higher horizons, were meager and not well preserved, so that their identification was difficult; they are, however, regarded by Knowlton as not Laramie, but possibly corresponding to the Livingston formation of the central part of the State, though showing decided Fort Union affinities. The beds are strikingly similar to the dinosaur-bearing beds on Hell Creek and presumably they are identical.

If the lowest principal coal bed is taken as the base of the Fort Union, then the dinosaur-bearing beds are 485 feet thick. If, however, the fossils found near the base of No. 7 are indicative of the base of the Fort Union, as thought by Knowlton, then the thickness of the dinosaur-bearing beds is only about 400 feet.

Perhaps the most favorable locality for the study of the dinosaur-bearing formation is the one already mentioned, in northwestern

Dawson County in the valley of Hell Creek. The section exposed there is as follows:

Section on Hell Creek.

	Ft.	in.
7. Clay and sand, light colored, light gray to buff; contains some massive sandstone and beds of coal 2 to 11 feet thick; many fossil leaves characteristic of the Fort Union are present; exposed to top of the ridges	115	
6. Clay and sand, similar in appearance to No. 4, but have yielded no dinosaur bones	100	
5. Coal, persistent; has been traced a distance of 25 miles	6	2
4. Clay and sand, mostly dark gray in color, with many brown, carbonaceous layers and some beds of coal. Two fairly persistent sandstone horizons, the lower about 15 feet and the upper about 20 feet thick, with 30 to 40 feet of clay between. These sandstones contain many large brown sandstone concretions. The beds yield dinosaur bones, such as *Triceratops*, *Claosaurus*, and *Tyrannosaurus;* also carry the remains of crocodiles, *Campsosaurus*, turtles, and ganoids, together with a few small mammal teeth	210–260	
3. Sandstone at the base of the dinosaur-bearing beds. Coarse grained and rather soft; characterized by its massiveness, absence of irregularity of bedding, the great number of large sandstone concretions, and its cross lamination; yellow or brown in color. Likewise contains dinosaur bones	50–100	
2. Clay, more or less sandy, and with some sandstone, light gray to buff, Fox Hills (?)	100	
1. Shale, Pierre, dark gray, with fossiliferous, calcareous concretions near the top; exposed above creek, about	150	

It will be seen from the above section that in this region between the top of the Fox Hills(?) and the base of the Fort Union, with its abundant and varied flora, there are only 400 feet of the dinosaur-bearing strata, even including the beds of No. 6, the age of which is not wholly beyond question.

In many places in northwestern Dawson County, particularly along the streams flowing into the Missouri, and in the badlands of the region, the dinosaur-bearing beds and overlying Fort Union are well exposed. At the head of Crooked Creek, which flows northward into the Missouri a few miles below Hell Creek, the following section was measured, beginning near the base of the Fort Union formation:

Section on Crooked Creek.

	Ft.	in.
46. Sand, yellow, with sandstone concretions to top of ridge	14	
45. Clay, gray	4	
44. Sand, gray	5	6
43. Sandstone yellow, persistent ledge	2–4	
42. Sand, fine, incoherent, yellow and gray	19	
41. Clay, sandy, gray	4	
40. Clay shale, brown	1	
39. Clay, gray	4	

	Ft.	In.
38. Clay, brown	1	3
37. Clay, gray	1	
36. Clay shale, brown, carbonaceous		6
35. Coal		3
34. Clay, gray, with plant stems	2	
33. Coal, impure; contains clay	1	8
32. Clay, gray, changing into brown above	1	
31. Sand, fine, argillaceous, yellow and gray	27	6
30. Coal, impure, and with seams of sand; this bed is continuous over a large area and forms a well-marked horizon 90 to 100 feet below the top of the dinosaur-bearing beds	5	6
29. Clay, brown, carbonaceous	1	6
28. Clay, gray	10	
27. Sand, fine, argillaceous, yellow, gray, shows cross lamination	13	
26. Sand, coarse, gray	18	
25. Clay shale, brown to black, carbonaceous	1	3
24. Clay, gray, sandy	11	
23. Clay, brown, carbonaceous, with several beds of coal, one 28-inch bed at top	10	
22. Clay, gray	2	6
21. Clay, more or less sandy, gray and yellow in alternating bands	1	6
20. Coal, impure, with three seams of sand	3	4
19. Clay, brown, carbonaceous	1	
18. Clay, gray, crumbles into flakes	2	
17. Sand, incoherent, yellow	1	6
16. Clay, gray	1	6
15. Sand, gray	5	
14. Clay, brown, carbonaceous	1	6
13. Clay, gray	2	6
12. Clay, brown, carbonaceous	1	2
11. Clay, sandy, light gray	5	6
10. Concretionary layer, brown, ferruginous		10
9. Clay, sandy, gray	5	
8. Clay, brown, sandy	2	6
7. Clay, gray	2	
6. Clay, brown, carbonaceous	1	
5. Clay, sandy, gray	24	
4. Sand, brown and yellow	6	
3. Sand, gray	5	
2. Clay, gray	2	
1. Clay, gray, sandy	7	
	245	3

Throughout the badlands which border the Missouri on the south, for a distance of over 50 miles above the mouth of Big Dry Creek, the dark-colored dinosaur-bearing beds, with many brown, carbonaceous layers, are overlain by the Fort Union.

FORT UNION FORMATION.

This formation presents a strong contrast to the underlying beds in this region and is readily distinguished by the light-gray and buff color

of its beds. The Fort Union contains thick beds of lignite and subbituminous coal, but brown carbonaceous clays seem to be rare. The sandstones of the formation abound in plants, which are exceedingly scarce in the underlying beds, but the latter contain dinosaur bones, as already stated, which are not found in the overlying Fort Union strata.

The following is a partial list of the plants collected from the Fort Union of this region and identified by F. H. Knowlton:

Onoclea sensibilis fossilis Newb.
Populus cuneata Newb.
Leguminosites arachioides Lesq.
Celastrus pterospermoides Ward.
Populus amblyrhyncha Ward.
Populus daphnogenoides Ward.
Populus arctica Heer (as identified by Lesquereux).
Populus smilacifolia Newb.
Populus nebrascensis Newb.
Populus genatrix Newb.
Populus speciosa Ward.
Cocculus Haydenianus Ward.
Platanus Haydenii Newb.
Platanus nobilis Newb.
Sequoia Nordenskiöldii? Heer.
Thuja interrupta Newb.
Glyptostrobus europæus (Brongn.) Heer.

In the vicinity of Miles, 100 miles to the south, the plants collected from several horizons are all considered by Knowlton to be undoubtedly Fort Union. Judged by their flora, practically all the beds about Miles are to be referred to this formation.

At Signal Butte, 5 miles east of Miles, the following section is exposed, extending from Tongue River to the top of the butte:

Section at Signal Butte, east of Miles.

	Ft.	In.
41. Clay, red from burning of coal bed; extending to top of Signal Butte	35	
40. Clay, sandy in part, crumbles readily in the hand, and some loose sand; light gray to buff in color and much lighter in appearance than the beds below; contains several thin, black streaks formed of black, carbonaceous dirt	160	
39. Clay, gray; contains large sandstone concretions and beds of sandstone near the top, containing plants	17	
38. Coal		2
37. Clay		9
36. Coal		9
35. Sand, gray	13	
34. Clay, brown, carbonaceous	3	
33. Sand and clay, light and dark gray in alternating bands	63	
32. Clay, brown, carbonaceous, with thin seams of coal		9
31. Clay, gray, with yellow, limonitic bands	11	
30. Coal, impure, contains clay seams	1	
29. Sand, with some clay, gray; contains many brown ferruginous nodules	27	
28. Coal		8
27. Sand, with ferruginous nodules	11	
26. Coal		8
25. Sandstone, rather soft	20	
24. Coal, good quality, with three thin clay seams; the Weaver mine is in this bed	5	6
23. Shale, brown	5	6
22. Sand, loose, yellow	22	

	Ft.	In.
21. Clay, brown, with thin beds of coal	5	
20. Clay and sand, gray	25	
19. Coal, impure, with clay seam 2 inches thick	2	3
18. Clay and sand, gray	22	
17. Coal, good quality, has been mined	2½-3	
16. Clay and sand	39	
15. Coal		6
14. Clay, brown, carbonaceous		7
13. Coal, upper part impure, but lower 3 feet of good quality; has been mined.	6	
12. Clay, yellow, containing sandstone beds and also concretions which break into yellow fragments. This member forms the top of the bluffs bordering the Tongue River Valley	17	
11. Clay, gray	2	
10. Coal, good quality	2	
9. Clay, yellow	8	
8. Clay, brown, carbonaceous, with some coal	1	
7. Clay, gray	2	
6. Coal	1	
5. Clay and sand, gray and yellow in alternating bands	66	
4. Sand, yellow, with sandstone concretions	5	
3. Clay, brown, carbonaceous	5	
2. Clay, gray	17	
1. Unexposed to river bank, estimated	75	
	702	1

At Signal Butte Fort Union plants were collected at only one horizon, No. 39 of the above section, which yielded the following species:

Taxodium occidentale Newb.
Sequoia Nordenskiöldii Heer?
Glyptostrobus europæus (Brongn.) Heer.
Populus? sp.? cf. genatrix Newb.
Populus, possibly P. acerifolia Newb.
Betula sp. new ?
Corylus rostrata Aiton.
Corylus americana Walter.
Planera.
Hicoria antiquorum (Newb.) Knowlton.
Hicoria? sp. new ?
Celastrus ovatus Ward.
Sapindus grandifoliolus Ward.

At a lower horizon in the bluffs of the Yellowstone at Miles other plants of Fort Union age were collected 115 to 125 feet above the river. The following species obtained from this locality were identified by F. H. Knowlton:

Populus cuneata Newb.
Populus amblyrhyncha Ward.
Populus nervosa elongata Newb.
Populus rotundifolia Newb.
Corylus americana Walter.
Hicoria? sp.
Platanus sp.
Cornus Newberryi Hollick.
Nelumbo n. sp.
Onoclea sensibilis fossilis Newb.
Trapa? microphylla Lesq., as identified by Ward.
Corylus rostrata Aiton.

The occurrence of the above plants at this horizon not far above the river is evidence that nearly all if not all the beds in the Signal Butte section belong to the Fort Union, and this formation thus has a thickness near Miles of 600 to 700 feet. The dinosaur-bearing beds

if present probably do not extend far above the level of the river, although if correlated solely on the basis of their close resemblance to the beds of the Hell Creek region, the lower 500 feet of the Signal Butte section would be referred to those beds. Only the upper 200 feet of the strata forming the butte resemble the Fort Union as it is developed 100 miles to the north.

STRUCTURE.

The geologic structure of the region under discussion is very simple, the beds for the most part being horizontal or with only a slight dip in certain localities. In the Hell Creek region, which is on the western margin of the field, the strata have a well-marked dip to the southeast, due no doubt to a general uplift to the west, which has brought the Pierre shale up to an elevation of at least 200 feet above Missouri River near the mouth of Big Dry Creek, southeast of Glasgow.

Reference has already been made to the anticline which shows so well on the Yellowstone at the mouth of Cedar Creek and on the opposite side of the valley. The dip is here 20° S. 52° W. and the strike is S. 38° E. This fold appears to be extensive, since it has brought the Pierre shale to the surface over a considerable area on Cedar Creek and it perhaps continues southeastward as far as Little Beaver Creek near the North Dakota line.

Smoke Butte, in western Dawson County, one of the most conspicuous buttes of the region, is composed of a mass of intrusive igneous rock forming part of a broad dike which can be traced for miles across the country. Smoke Butte stands at the junction of Smoke Butte and Big Dry creeks, 9 miles west of the town of Jordan. It rises 360 feet above Smoke Butte Creek. The dike has a width of 60 to 70 feet and its trend ranges from N. 48° E. to N. 53° E. Its course is marked by a line of ridges and detached buttes which owe their origin to the resistant character of the rock forming them. A smaller dike branching off from the main one has a width of 3 feet and shows columnar jointing, the columns being horizontal.

COAL.

GENERAL CHARACTERISTICS.

The coal beds are not confined to any particular horizon, but are distributed from top to bottom of the Fort Union formation. Sections in western North Dakota show that the lignite beds have a vertical range of 1,500 feet or more. Few exposures of 300 or 400 feet of strata do not contain at least thin beds of lignite. In some places but two or three such beds are present; in others there are ten or fifteen in a vertical distance of 250 to 500 feet, although many of the beds are only a few inches thick.

Over the field generally the coal beds range in thickness from a fraction of an inch to 14 feet. Beds 6, 8, and 10 feet thick are not uncommon, but those over 10 feet are comparatively rare.

The beds are usually not continuous over very large areas. A particular coal bed will pinch out within a mile or two and perhaps be replaced by another at about the same or a different horizon. Or two may overlap each other and while both appear at one point, at another point half a mile or so distant only one of them is present. In many places it is not possible to correlate beds on the opposite sides of the same valley and only 1 or 2 miles apart. On the other hand, here and there one coal bed can be traced 3 or 4 miles in the river bluffs and less commonly twice that distance, but sooner or later it thins out and disappears. This lack of persistence makes it unsafe to correlate coal beds whose outcrops are separated by more than a few miles.

Practically all the coal of this field is subbituminous (black lignite). Some of the beds, which are made up largely of the black variety, contain thin layers of brown lignite, but nowhere was the latter found to constitute the entire bed. The area is different in this respect from the North Dakota field, where the coal is entirely brown. In eastern Montana the coal is black and brittle and usually has a bright luster. Although some of it shows a woody structure, this is much less common than in the brown lignite, which is also generally tough rather than brittle.

On exposure to the air the coal loses part of its moisture, begins to crack, and finally breaks up into small fragments. This change takes place much more readily in the coal of some beds than in that of others. At some outcrops observed the material must have been exposed for many months, but back several inches from the face the coal still had the appearance of being fresh and unaffected by the weather. On the other hand, some beds, after no longer period of exposure, show the effects of weathering for a distance of several feet from the surface.

In many of the beds the coal is cut by one or two systems of joints, which are vertical, or nearly so, and from 5 or 6 inches to 1 foot and more apart. These joints are usually very clear cut and regular.

The following analyses show the composition of this subbituminous coal from several localities. Each sample was cut in the mine across a working face of the bed and then pulverized and quartered down to a quart sample, which was sealed air-tight in a galvanized-iron can and mailed to the chemical laboratory at St. Louis. Analyses were made under the supervision of N. W. Lord at the fuel-testing plant of the Geological Survey by F. M. Stanton, chief chemist.

Analyses of subbituminous coal samples from Montana.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Laboratory No.	2424.	2429.	2425.	2426.	3701.	3782.	3783.	3842.	2423.	3812.	3816.
Analysis of sample as received:											
Prox. Moisture	26.84	28.47	30.25	33.53	29.13	31.29	35.16	31.33	34.94	34.55	34.89
Prox. Volatile matter	32.14	28.63	30.48	25.82	25.33	26.57	26.08	24.57	26.99	35.34	43.48
Prox. Fixed carbon	34.19	35.32	31.34	29.37	30.51	35.24	35.70	30.77	32.46	22.91	13.56
Prox. Ash	6.83	7.58	7.93	11.28	15.03	6.90	3.06	13.33	5.61	7.20	8.07
Ult. Sulphur	.31	.69	.60	.68	.55	.46	.31	.37	.74	1.10	1.33
Ult. Hydrogen	.....	.....	.....	.....	5.60	.....	.....	.....	.....	6.60	6.41
Ult. Carbon	.....	.....	.....	.....	40.09	.....	.....	.....	.....	42.40	41.66
Ult. Nitrogen	.....	.....	.....	.....	.54	.....	.....	.....	.....	.57	.56
Ult. Oxygen	.....	.....	.....	.....	38.19	.....	.....	.....	.....	42.13	41.97
Calorific value determined:											
Calories	.....	.....	.....	.....	3,701	.....	.....	.....	.....	3,939	3,880
British thermal units	.....	.....	.....	.....	6,662	.....	.....	.....	.....	7,090	6,984
Loss of moisture on air drying	17.50	20.30	21.90	25.60	16.50	14.80	22.30	20.30	27.40	15.50	14.20
Analysis of air-dried sample:											
Prox. Moisture	11.32	10.25	10.70	10.66	15.12	19.36	16.54	13.84	10.38	22.55	24.11
Prox. Volatile matter	38.96	35.92	39.02	34.70	30.34	31.18	33.57	30.83	37.18	41.82	50.68
Prox. Fixed carbon	41.44	44.32	40.13	39.48	36.54	41.36	45.95	38.61	44.72	27.11	15.80
Prox. Ash	8.28	9.51	10.15	15.16	18.00	8.10	3.94	16.72	7.72	8.52	9.41
Ult. Sulphur	.38	.86	.77	.91	.66	.54	.40	.47	1.02	1.30	1.55
Ult. Hydrogen	.....	.....	.....	.....	4.51	.....	.....	.....	.....	5.77	5.63
Ult. Carbon	.....	.....	.....	.....	48.01	.....	.....	.....	.....	50.18	48.55
Ult. Nitrogen	.....	.....	.....	.....	.65	.....	.....	.....	.....	.68	.65
Ult. Oxygen	.....	.....	.....	.....	28.17	.....	.....	.....	.....	33.55	34.21
Calorific value determined:											
Calories	.....	.....	.....	.....	4,432	.....	.....	.....	.....	4,662	4,522
British thermal units	.....	.....	.....	.....	7,978	.....	.....	.....	.....	8,391	8,140

1. On Clear Creek, 12 miles southwest of Glendive, Dawson County; bed 4½ feet thick.
2. Across the Yellowstone from Fallon, at mouth of Cottonwood Creek, Custer County; bed 6½ feet thick.
3. Five miles northeast of Miles.
4. In cut bank of Yellowstone at Fallon, Custer County; sample taken from face of outcrop of bed 4 feet 8 inches thick.
5. Five miles east of Miles.
6. At head of Youall Creek, T. 12 N., R. 45 E., Custer County; sample taken from outcrop.
7. Near head of Crow Rock Creek, T. 12 N., R. 45 E., Custer County; sample taken from outcrop, representative pieces of coal being selected near center of bed.
8. At Jordan, Dawson County; sample taken near face of outcrop.
9-11. Eight miles north of Glendive, Dawson County.

DESCRIPTION OF THE COAL BEDS.

Some of the coal beds of Dawson and Custer counties have already been described,[a] and only those which were examined during the last season (1906) will be considered here.

SHEEP MOUNTAIN REGION.

Big Sheep Mountain and Little Sheep Mountain are located in southern Dawson County, about midway between its eastern and western boundaries and almost due north of Miles. As already stated, they form the highest part of the divide separating the tributaries of the Yellowstone from those of the Missouri. Several coal beds occur in the vicinity of McMillan post-office in T. 14 N., R. 47 E., on West Fork of Cherry Creek. Four miles northeast of the post-office there is a 6-foot bed, and what is probably the same bed outcrops near the base of Big Sheep Mountain. Just south of Little Sheep Mountain, in a gully beside the stage road from McMillan to Miles, a bed 7 feet thick outcrops.

[a] Bull. U. S. Geol. Survey No. 85, 1906, pp. 327-329.

MILES DISTRICT.

North of Yellowstone River, on Sunday Creek and its tributaries, coal outcrops at many points in Tps. 8, 9, and 10 N., R. 47 E. It has been mined for several years just below the bridge over South Sunday Creek, in sec. 18, T. 8 N., R. 47 E. The bed outcrops in the cut bank along the stream for a distance of 300 feet and lies only 2 to 3 feet above the bed of the creek. It is from 4 to 4½ feet thick and the coal is of good quality. The section is as follows:

Section of coal bed on South Sunday Creek.

	Feet.
Sand and clay, washed from higher slopes	15
Sandstone, soft	8
Coal, with 1-inch seam of sand, 1 foot below top	4–4½
Clay, exposed to bed of creek	2–3

Mining is carried on here partly by stripping, the soft sandstone being blasted off in large blocks, and partly by drifting in along the bed. The coal is mined only during the winter and is sold in Miles. The same bed appears along North Sunday Creek and outcrops along the road about half a mile north of the bridge.

Several miles below the junction of the two creeks, in sec. 9, T. 8 N., R. 47 E., a coal bed 3 feet 4 inches thick is exposed on the north side of the valley.

In the high ridge 2½ miles northwest of the mouth of Sunday Creek, in sec. 22, T. 9 N., R. 47 E., a bed 7½ feet thick is present. It is badly weathered on the face of the outcrop and back several feet from the surface has crumbled to powder.

On Cow Creek, a tributary of Sunday Creek which crosses T. 9 N., R. 47 E., from northwest to southeast, a 10-foot bed of coal is exposed at a number of points from 5 to 10 miles above the mouth. The bed appears to be continuous over a considerable area and is only a few feet above creek level. In places the coal has burned and its horizon is represented by red clay, and much of the bed has been eroded by the branches of Cow Creek. At the outcrop the coal is overlain by only a few feet of clay, but it doubtless extends back from the creek and is present under the bluffs which rise abruptly at a distance of one-half to 1 mile.

Several beds of impure coal occur in the bluffs near the head of a small creek about 2 miles west of and nearly parallel with Cow Creek in T. 9 N., R. 46 E.

On South Sunday Creek, 5 or 6 miles above its junction with North Sunday and near the Reynolds ranch, a coal bed 3 feet thick is mined for use near by.

In the badlands about 18 miles north of Miles, or 9 miles from the ferry across the river near Tusler, a thick bed is exposed along the stage road to McMillan. The section is as follows:

Section of coal bed 18 miles north of Miles.

	Ft.	In.
Clay, yellow	9	
Coal	10	6
Clay and coal in alternating seams, the clay bands 1 to 8 inches thick	5	6
Coal	2	6
Clay, exposed to creek	4	
	31	6

Including the several clay seams the bed has a thickness of over 18 feet. It appears at intervals for more than half a mile, one outcrop being 300 feet long. The coal is of good quality.

Two thin beds of coal are exposed in the steep bluffs of the Yellowstone opposite Miles. The lower, which is only 27 inches thick, can be followed by its outcrops for a distance of at least 2 miles. It has been mined at many points by running short drifts in along the bed.

By far the greater part of the coal used in Miles comes from the Kircher and Weaver mines on the south side of the river. The former is located 5 miles northeast of town, and the latter about the same distance to the east, near the base of Signal Butte.

The Kircher Brothers' mine, in sec. 19, T. 8 N., R. 48 E., is working a bed ranging in thickness from 4 feet 2 inches to 4 feet 6 inches and lying about 75 feet above the river. The coal is reached by a slope 136 feet long and lies 58 feet below the entrance of the slope. The coal is cut by vertical joints, 18 inches to 2 feet apart, which serve to block it out and assist in mining, the coal coming out in good-sized pieces. A main entry extends in opposite directions from the bottom of the slope for a distance of about 400 feet. From this entry rooms 200 feet long are turned and 6-foot pillars are lett between the rooms. Several inches of coal are left at the top and little timbering is necessary, since this forms a secure roof. The mine is worked during the entire year, 25 to 30 men being employed during the winter. The coal is of excellent quality, black, brittle, and with bright luster.

The Weaver mine is on a higher bed, 330 feet above the Yellowstone, and the section here is as follows:

Section of coal bed at Weaver mine.

		Ft.	In.
11.	Sandstone, gray and rather soft, but forming good roof	20	
10.	Clay, brown, carbonaceous, with some plant fragments		10
9.	Coal, good quality	2	2
8.	Clay		1
7.	Coal		2
6.	Clay		3

	Ft.	In.
5. Coal	1	5
4. Clay, brown, carbonaceous		4
3. Coal	1	2
2. Clay, brown, carbonaceous	5	7
1. Sand, soft, yellow	22	
Total coal bed	5	7

Nos. 5 to 9, inclusive, are removed, 4 feet of coal and the included clay seams being mined. The bed is exposed at a number of points in the sides of Signal Butte and probably underlies the entire butte. Two lower coal beds which outcrop below the mine have also been worked by Mr. Weaver in past years. They are shown in the Signal Butte section on pages 201–202. One lies about 130 feet below and has a thickness of 6 feet, but the upper half of the bed is a poor, impure coal; the other, 2½ to 3 feet thick, contains good coal, but has a poor roof.

Thick coal beds occur in the Pine Hills east of Miles, which have an elevation of 700 feet above Yellowstone River. One of these beds, 12 to 15 feet thick, is exposed at numerous points about 10 miles from town, in secs. 9, 10, 12, 14, 15, 22, and 23, T. 7 N., R. 49 E. The coal lies not far below the top of the hills and has burned out over large areas, as shown by the abundance of red clay.

REGION BETWEEN MILES AND JORDAN.

The town of Jordan is located on Big Dry Creek, in western Dawson County, and is 92 miles northwest of Miles. Between these two places there are many coal beds within a few miles of the stage road. The most important of these will be described in the order of their occurrence northward from Yellowstone River.

In the bad lands on Grimes Creek, a tributary of North Sunday Creek, in T. 10 N., R. 45 E., a bed of coal 2 feet 6 inches thick outcrops for a distance of several miles in the bare clay slopes of the bluffs. A bed of the same thickness appears on Alkali Creek 3 miles above its junction with Grimes Creek at the Stone shack.

One or more thick beds of coal occur in T. 12 N., R. 45 E., the extreme northwestern township of Custer County. They are exposed in the deep ravines near the heads of Youall and Crow Rock creeks, both of which flow north into Little Dry Creek. About 4½ miles east of Sim Robert's ranch a bed of coal 10 feet thick outcrops at the head of Youall Creek, in sec. 20, T. 12 N., R. 45 E. It is of excellent quality, black and with a bright luster. The coal is jointed, the joint cracks being from 10 to 18 inches apart. The bed is overlain by 40 to 50 feet of buff clay. About 5 miles farther northeast, near the

head of Crow Rock Creek, what is perhaps the same bed outcrops. It is 8½ to 9 feet thick and is overlain by 8 to 10 feet of buff sandstone and 20 to 30 feet of yellow clay, mostly wash from higher slopes. The coal, though black and brittle, shows plainly the woody structure.

Several miles southeast of Satchwell post-office, near the northern border of Rosebud County, a bed of coal 2 feet 6 inches thick occurs under a cover of 3 or 4 feet of clay. It is near the top of the divide separating the Missouri from the Yellowstone drainage.

At Joe Greer's place, on Thompson Creek, 4 to 5 feet of coal is exposed and is mined close beside the house by drifting in along the bed. A spring flows from the bottom of the bed.

There are two beds of coal in the vicinity of Cohagen post-office on Little Dry Creek. One of these is well exposed for 300 yards in a cut bank along the stream. The section here is as follows:

Section of coal beds at Cohagen.

	Feet.
5. Clay washed from higher slopes.	
4. Coal	5
3. Clay	6
2. Coal, upper 5 or 6 feet of poor quality from admixture of clay, also contains iron pyrites in nodules; lower 3 or 4 feet of good quality	9
1. Clay, exposed to creek bed	1
	21

In places the upper part of the coal bed has suffered erosion and is overlain by several feet of sand and gravel upon which rest 3 to 10 feet of wash clay.

About 1½ miles southwest of Cohagen, on Phillips Creek, a tributary of Little Dry Creek, another bed is exposed, the section being as follows:

Section on Phillips Creek.

	Ft.	In.
10. Sand and clay	9	
9. Coal		6
8. Clay, brown	1	6
7. Coal		1
6. Clay, brown	1	2
5. Coal		5
4. Sand seam, brown		1½
3. Coal	3	6
2. Clay, gray	6	
1. Unexposed to creek	15	
	37	3½

The coal of the 3½-foot bed (No. 3) is a good subbituminous coal, with bright luster and brittle. It is well jointed, the joint cracks being from 1 to 4½ inches apart.

Two beds appear on Sand Creek near the road crossing, as shown in the following section:

Section on Sand Creek.

	Ft.	In.
8. Clay, alluvial, and silt	9	
7. Gravel and sand	4	
6. Clay, brown	1	
5. Coal, impure, dull	1	6
4. Clay, jointed, gray	15	6
3. Coal, mostly black, with bright luster, shows bedding plainly, being composed of layers one-half to 4 inches thick	2	
2. Sand, gray	2	
1. Clay, gray, exposed to creek level	4	
	39	

The upper bed outcrops at intervals along the creek for a distance of 1 to 2 miles.

The section which follows is exposed in the steep cut bank of Big Dry Creek at Jordan:

Section at Jordan.

	Ft.	In.
13. Clay, washed from upper slopes	2	
12. Clay, gray, jointed	9	
11. Clay, brown, carbonaceous, with some coal		4
10. Coal, impure, with 1-inch clay seam	1	9
9. Clay, brown, carbonaceous		6
8. Coal, good quality except upper 3 or 4 inches	2	2
7. Sand seam, brown		2
6. Coal, good quality	1	8
5. Clay, gray	1	6
4. Sand, gray	2	
3. Clay, gray	3	
2. Coal		6
1. Clay, blue, to bed of creek	1	
	25	7

The beds have a slight dip to the east. The outcrops appear in the banks of the creek for over half a mile and the coal doubtless extends back under the slopes south of the stream. At the lower end of the exposure the bed is cut out by erosion and is replaced by alluvial clay. Nos. 6 and 8 of the above section together form a 4-foot bed of coal of excellent quality, with a 2-inch seam of sand near the center. The coal, which is black and has a bright luster, is in distinct layers and breaks readily along the bedding planes.

REGION NORTH OF JORDAN.

At Percy Williamson's ranch, about 13 miles north of Jordan, a bed of good black subbituminous coal is mined on its outcrop for use on the ranch. Only 3 feet is exposed, but the bed is said to be 5 to 6 feet thick. A massive sandstone with a thickness of 30 to 40 feet occurs over the coal.

Beds of coal occur in the dinosaur-bearing beds and the Fort Union formation of the Hell Creek district. A very persistent bed about 6 feet thick lies 100 feet below the Fort Union, and this has been traced at least 25 miles.

COAL FIELDS IN A PORTION OF CENTRAL UINTA COUNTY, WYO.

By Alfred Reginald Schultz.

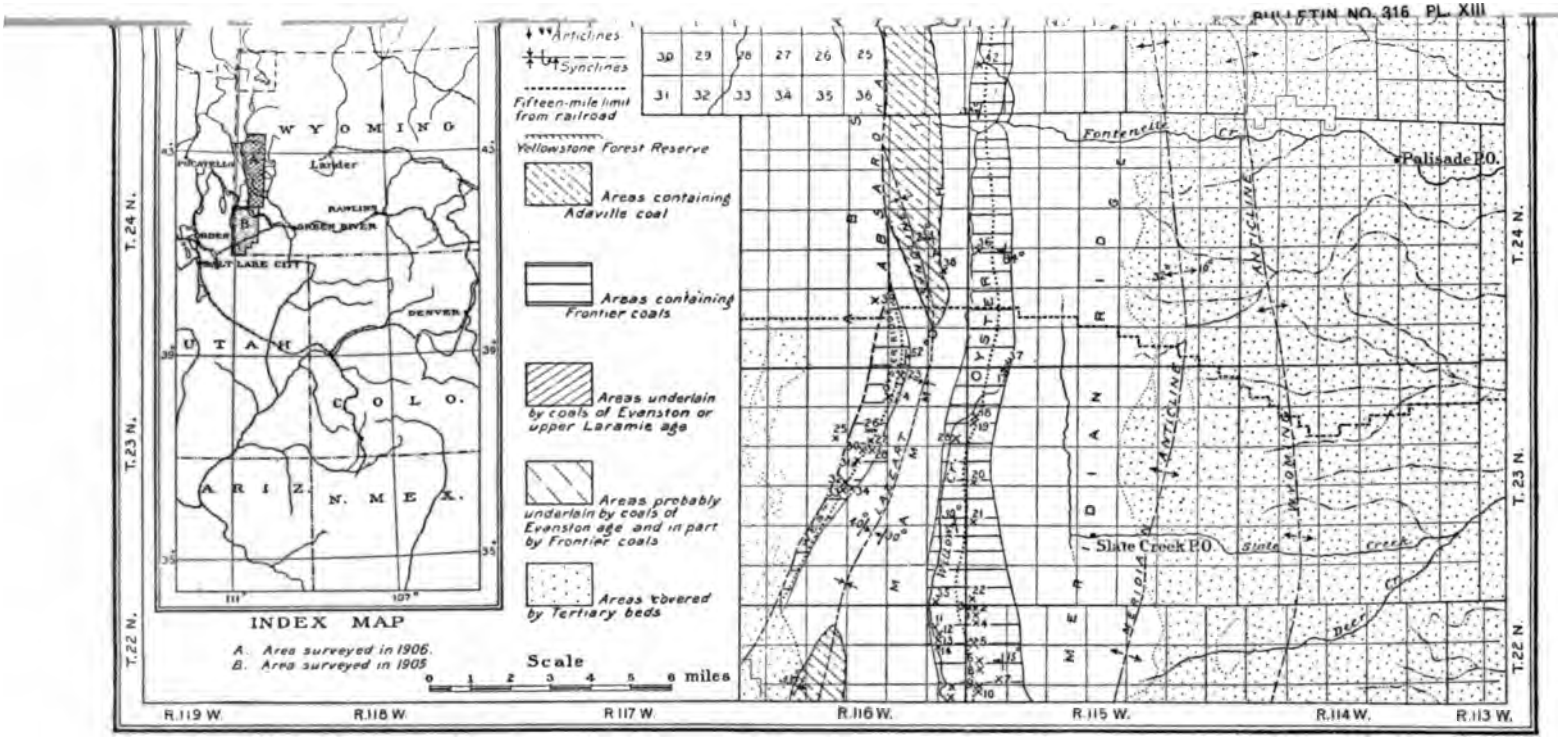
INTRODUCTION.

The present paper comprises a brief preliminary statement of some of the results obtained from surveys made by E. E. Smith, B. A. Iverson, H. C. Schleuter, and the writer during the summer of 1906 in Tps. 23 to 39 N., Rs. 113 to 117 W., inclusive, Uinta County, Wyo.[a] The examination of this region was made primarily for the purpose of determining the outcrop of the various coal-bearing rocks and oil beds and to trace northward the coal formations mapped by A. C. Veatch and the writer in southern Uinta County during the summer of 1905.[b] In carrying on this work the surveys were carefully tied to land corners, and geologic and sketch topographic maps were prepared on a scale of 2 inches to the mile, with a contour interval of 100 feet. The data collected have been compiled into a single base map on the scale of 1 inch to the mile, which shows all the streams, land corners, houses, fences, roads, and trails found in this examination and will accompany the complete report of this area. This map shows the areal and structural geology, the location and depth of the coal beds, the location of the oil-bearing shales, the occurrence of iron and gold, and the regions where they may be found. It is the purpose in this preliminary report to give a short description and summary of the occurrence and distribution of the coal-bearing formations in this field and to point out to what extent development has been carried. The accompanying map (Pl. XIII) is a reduced copy of the base map above mentioned.[c]

[a] A complete detailed report of this work will be issued later as a separate publication of the Geological Survey.

[b] For results of the survey made in 1905 see Prof. Paper U. S. Geol. Survey No. 56 and Bull. U. S. Geol. Survey No. 285, 1906, pp. 331-353.

[c] Recent work has shown that the areas mapped as Evanston on the east side of Labarge Ridge are Adaville and that the contact between them and the older rocks on the west is a fault instead of a depositional contact as shown on the map.



MAP OF THE COAL FIELDS OF CENTRAL UINTA COUNTY WYO.

By A. R. Schultz, assisted by E. E. Smith, 1906. (See footnote, p. 212.)

SURFACE FEATURES.

This region has an elevation ranging from 5,700 feet on Snake River to 11,500 feet along the crest of the mountain ranges. In the vicinity of Sheep Creek, a tributary of John Day River, where the most rugged topography is encountered, there is in some places a difference of elevation of 3,000 feet in less than half a mile. The area is traversed from west of north to east of south by two parallel mountain ranges—Salt River Range and Wyoming Range—and is bounded on the northeast by the Gros Ventre Mountains, which extend in an east-southeast and west-northwest direction. Near the south end of the area mapped the Salt River and Wyoming ranges become lower, passing into Absaroka Ridge and Meridian Ridge, respectively, and they finally lose their topographic identity south of the area, where the rocks of which they are composed are deeply buried by Tertiary deposits. There are numerous ridges or folds rudely parallel to the main ridges, the most important being the Hoback Range, which connects the Wyoming Range and the Gros Ventre Mountains. East of the parallel mountains is the great plainlike basin of Green River, which has a mean elevation of about 7,500 feet. The entire area except this narrow strip along the eastern margin is a succession of rugged mountain peaks and ridges cut by numerous gorges and canyons, whose walls are in places nearly perpendicular. Many of the hills, valleys, and slopes are well timbered with pine, fir, and spruce.

The drainage belongs to three great systems—Snake River, whose waters flow into the Pacific; Green River, whose waters flow into the Gulf of California; and Bear River, whose waters enter the Great Basin. The greater part of the drainage is almost equally divided between Snake and Green rivers, with a margin in favor of Snake River, only a small area in the southwestern portion being drained by the tributaries of Bear River.

STRATIGRAPHY.

The survey of last summer was carried on with special reference to coal, most of the work being restricted to the coal-bearing formations. As much attention as possible was devoted to the formations contiguous to the coal-bearing rocks, and sufficient information regarding their age was obtained to correlate them with similar beds in other parts of the country. The fossils collected by this party and studied by Walcott, Stanton, Girty, Knowlton, and Dall, as well as material collected by former expeditions in this area, particularly those of the Hayden Survey, indicate that the several formations studied and mapped in the field have the geologic time values given in the accompanying table and agree very closely with the sections studied in southern Uinta County during the summer of 1905.

Succession, age, and thickness of beds in central Uinta County, Wyo., to the base of the Cretaceous.

System.	Names used previously or in adjacent regions.	Formation.	Thickness.	Character of strata.	Where exposed.	Economic value.
Quaternary.	Quaternary.		*Feet.* 0-250	Hill wash, valley filling, flood plain deposits and small stream bottoms accompanying river filling.	Throughout area.	Clay deposits derived largely from the weathering of underlying shales in Mammoth Valley have been used for making brick near Glencoe, but are not developed farther north.
			0-150	River terraces.	Snake River and tributaries.	Gold placers worked along Snake River. Similar auriferous-gravel deposits occur both up and down Snake River beyond this area and on some of its tributaries.
		Pleistocene.	1-150	Bowlders, gravels, and ground-moraine material associated with hill wash.	South flank of Gros Ventre Mountains.	
		Unconformity.				
Tertiary.	Green River.	Green River.	[a] 2,000	Thin-bedded shales, sandstones, and limestones, for the most part light colored.	On Green River plain west of Green River and east of Meridian Ridge and Wyoming Range.	
	Wasatch.	Knight.	[b] 500	Beds of red and yellow sandy clays interlaminated with white, gray, and yellow sandstones. Local areas of concretionary limestone.	East of Meridian Ridge, Wyoming and Hoback ranges.	
		Unconformity.				
		Almy.	[c] 2,500	Red and yellowish-white conglomerates, sandstones, and sandy clays.	Snake and Fall rivers south of Gros Ventre Mountains and east of Hoback and Wyoming ranges.	
	Upper Laramie.[d]	Evanston.[e]	[f] 9,500	Gray and yellow shales and clays, with gray and yellow sandstone beds, containing several minor coal beds, none of which are developed. Same age as the Almy coals near Evanston, Wyo., usually called Upper Laramie. Invertebrates common to the Laramie and Fort Union. In this region these beds rest upon Jurassic, Carboniferous, and Cambrian beds.	East of Hoback Range both north and south of Fall River and south of Gros Ventre Mountains; also the beds east of Labarge Mountain north of Labarge Creek. Structurally these beds are Evanston, but they contain typical Adaville fossils and may be Adaville.	Several minor coal beds of workable thickness have been observed. None have been prospected or developed. Coal similar to the Evanston and Almy coals of southwestern Uinta County. At Sayle's mine a 180-foot tunnel has been opened in a 6-foot bed and considerable coal mined for local use. Several other mines supply coal for ranch use.

Unconformity.

Cretaceous.	Montana.	Lower Laramie.	Adaville.	2,800	Gray, yellow, and brown clays and shales with irregularly bedded brown and white sandstones and numerous beds of coal. The lower beds of this formation contain plants and invertebrate remains that are referred to the uppermost Montana; the upper beds contain lower Laramie leaves.	East of Absaroka Ridge and west of Oyster Ridge on South Fontenelle Creek.	Contains many beds of workable coal. A few prospect pits only are opened in this area.
	Colorado.	Niobrara.	Hilliard.	3,000	Gray and black sandy shales and shaly sandstones that weather readily and afford few exposures. Usually a region of low relief.	Between Oyster Ridge and Absaroka Ridge and east of Wyoming Range on Piny Creek.	
		Benton.	Frontier.	2,400 to 3,800	Alternating beds of gray and yellow clays, shales, and sandstones containing numerous beds of coal. Forms pronounced ridges or hogbacks in southern part of area east of Absaroka Ridge. Near top of formation is a pronounced bed of coarse sandstone, locally conglomeratic, containing numerous large oysters. This is the Oyster Ridge sandstone. Farther north this formation loses its characteristic hogback topography east of Salt River and Wyoming ranges.	East of Absaroka Ridge, Salt River Range, and along the east side of Wyoming Range.	Contains numerous beds of coal throughout the area. Farther south the Kemmerer, Willow Creek, Carter, and Spring Valley coals have been developed. The Kemmerer coals are extensively mined at Frontier, Diamondville, Oakley, Glencoe, and Cumberland. Within this area only Wright's mine and a few prospect pits have been opened, the coal being supplied to ranchers. Contains good building stone.
			Aspen.	1,200 to 1,800	Gray and black shales, shaly sandstone, and beds of compact gray sandstone and bluish limestone containing fish scales; commonly weathers silver-gray and shows little white specks in some of the sandstones.	East of Oyster Ridge, Absaroka Ridge, and Salt River Range, also east of Wyoming Range, north of Piny Creek.	Contains oil developed in wells northeast of Spring Valley, and probable source of oil in Hilliard, Carter, and Fossil oil springs. In this area no prospecting for oil has been carried on.
	Bear River.		Bear River.[g]	800 to 1,500	Black shale, shaly sandstone, and shaly limestone with abundant invertebrate fossils. Several thin beds of coal and bituminous shale.	Between Meridian and Absaroka ridges, Wyoming and Salt River ranges, and Wyoming and Hoback ranges.	Coal beds so far as noted are too thin and impure to be of any value. Oil in this formation southeast of Spring Valley in two wells.

[a] Estimate of Clarence King of maximum thickness in Green River basin southeast of this region; only a portion of the beds occur in this area.
[b] Only a portion of the Wasatch beds present in this area.
[c] Total thickness of beds probably not present in the region.
[d] Near Evanston, Wyo., these beds have been called Wasatch by White and Laramie by Hayden and King.
[e] Evanston as here used is the same as the Evanston formation in southwestern Uinta County. See Contributions to Economic Geology, 1905: Bull. U. S. Geol. Survey No. 285, 1906, pp. 332-335. C. A. White (Eleventh Ann. Rept. U. S. Geog. and Geol. Survey Terr., 1879, pp. 240-241) used the name "Evanston coal series" in referring to the coal-bearing beds of Almy below the Wasatch and above the Bear River. Lesquereux (Sixth Ann. Rept. Geol. Survey Terr., 1873, p. 409) used the term "Evanston deposits."
[f] Upper limit not seen.
[g] The Bear River beds are underlain by marine Jurassic. The beds appear apparently conformable. Other evidence seems to indicate that an unconformity exists between the Bear River and Jurassic beds. The oldest rocks studied in this area are of Cambrian age.

STRUCTURE.

The main disturbance in this area occurred near the close of the Cretaceous period, during the interval marked by the unconformity between the Adaville and Evanston formations. A second and minor disturbance occurred after the deposition of the Evanston beds. The movement during this disturbance was for the most part along several of the old lines of weakness, faulting and tilting the younger beds so that they now dip in some places from 40° to 50° and in an opposite direction to the older underlying beds. An earlier disturbance than these two may have occurred between the deposition of the Jurassic and that of the Bear River. There is some evidence that the Lower Cretaceous and the Dakota of the Upper Cretaceous (unless the Bear River is the equivalent of the Dakota) are wanting in this area, but this has not been proved. There was, however, at that time no great disturbance associated with folding and faulting, for throughout the area the Bear River beds are apparently conformable upon the known Jurassic beds.

The main structural features of this region are parallel to each other and have a north-south trend with a slight westward deflection, which increases toward the north. They are the direct northward continuation of the faults and folds observed in southern Uinta County. The important structural features at the south end of the area, named in order from east to west, are (1) a fairly regular anticline with two or more secondary folds—the Meridian anticline; (2) a rather regular syncline, in places slightly overturned—the Lazeart syncline; (3) a large and persistent faulted anticline, with its downthrow to the east and a displacement of 15,000 to 20,000 feet; (4) a broad syncline—the Fossil syncline—which lies for the most part west of this area. Farther north the structural conditions are more complicated. Several additional folds and faults occur and the entire region is more disturbed, giving rise to the Hoback, Wyoming, and Salt River ranges.

The important structural features at the north end of the area, named in order from east to west, are (1) a rather irregular, complex anticlinorium, which gives rise to the Hoback Range and passes toward the south into a regular anticline, in places slightly overturned—the Hoback anticline; (2) the eastern portion of a synclinorium, the south end of which is a monocline with beds dipping from 25° to 45° W.—the Lander syncline; (3) a faulted anticline with its downthrow to the east and a displacement of about 20,000 feet—the Wyoming anticline; (4) the northward continuation of the Lazeart syncline, which develops a secondary fold in the vicinity of Snake River—the John Day River syncline;[a] (5) the northward

[a] This appears on Pl. XIII as the Greys River syncline, but as the United States Geographic Board has decided that the river should be known as the John Day, the structural feature should carry the same name.

continuation of the Absaroka fault, which here lies along the east base of the Salt River Range. The displacement along this fault is somewhat greater than at the south end of the area, approximating 20,000 feet. The Salt River Range has been uplifted and its component rocks thrown into sharp folds. As most of the range lies west of this area, no detailed sections were made across it, but very probably it exhibits the same type of structure as the Hoback Range. The faulted anticline (3) gives rise to the Wyoming Range, and the fault extends approximately along the east base of the range in much the same manner as the Absaroka fault along the east base of Absaroka Ridge and the Salt River Range. Near the south end of the Wyoming Range the anticline develops into two or more secondary folds. South of the Wyoming Range the fault is connected with the Absaroka fault by a cross break which continues eastward north of Thompson Plateau and in which the downthrow is on the south, with a displacement of about 5,000 feet.

The structural features that are of the greatest importance in the consideration of the coal deposits are the following:

1. The Lazeart syncline and its northward continuation, or John Day River syncline, lying between the Salt River and Wyoming ranges. In places the Lazeart syncline is entirely overturned; the beds of the lower limb dip from 25° to 40° W., and those of the upper or west limb dip from 45° to 90° W., giving an overturn dip of 135°. North of Wrights Ranch the syncline becomes regular; the beds on the east limb dip to the west and those on the west limb dip to the east, but a portion of the west limb is removed by the encroachment of the Absaroka fault. Still farther north the syncline rises, and north of South Fontenelle Creek the beds of the west limb dip 50° to 80° E., while the beds of the east limb dip 25° to 30° W. North of Fontenelle Creek the east limb only remains. Farther north the John Day River syncline shows some complexity, and in the vicinity of Little John Day and Snake rivers a secondary fold parallel to and about halfway between the Wyoming and Salt River ranges is developed.

2. The Lander syncline, lying between the Wyoming Range and the Hoback anticline, to the east. The beds in this syncline are chiefly of Cretaceous age. They are somewhat disturbed, but for the most part they dip toward the west at angles varying from 15° to 50°.

The two structural features just described contain all the best coal beds in this region. East of Hoback and Labarge ranges, on the gently eastward-sloping plain along the western margin of the Green River basin, there is another coal field containing the Labarge Mountain and Fall River coals. The coal beds of this field are of a much later age and they probably extend over a large portion of the Green River basin. Their outcrops, however, are of very small extent, for the Tertiary covering has been removed in only a few localities. The

dips are for the most part toward the east and range from 10° to 45°. The coal-bearing formations studied in the Lander syncline west of the Hoback anticline probably occur also along the east side of the anticline, but nothing is known of their distribution outside of a small area in T. 30 N., R. 115 W., in the east-central part of sec. 24, owing to the heavy covering of Tertiary beds, which in many places extend high up on the Hoback Range and completely bury the Hoback anticline. Until drill holes have been put down through the Tertiary cover, the position, distribution, and thickness of these coal beds can only be inferred.

COAL.

GENERAL CONDITIONS.

Geologic study of this region, and particularly of the coal-bearing formations, is of especial economic interest. At present the coals are scarcely known north of Kemmerer and are but little developed. In a few localities enough coal is taken from shallow pits to supply the ranches in the immediate vicinity. Outside of this local mining, no development work is carried on in the region. The talus and heavy growth of timber covering the slopes are obstacles to a thorough investigation, but a considerable number of prospect pits in which the coal beds range from 2 to 20 feet in thickness have been examined. The coal taken from some of these pits resembles the bituminous coals of southern Uinta County, which belongs near the top of the group containing the best bituminous coals of the Rocky Mountain region. Although the mapping of the formations was not continued north and west of Snake River, the coal-bearing rocks extend to the northwest for a considerable distance and probably across the Wyoming State line south of Teton Pass. In the vicinity of Victor, Oasis, and Haden, on the eastern slope of the Pierres Hole (Big Hole) Mountains, in Idaho, occurs a series of coal-bearing rocks that dip from 40° to 50° SW. These rocks, which may be a continuation of the coal-bearing formations south and east of Snake River, are known to contain seven coal beds ranging in thickness from 2 to 20 feet. The coal is of unusually high quality and makes a very desirable fuel for steam and domestic purposes. It also shows coking properties, and some very fine samples of coke have been obtained in laboratory tests.

Thus far coal prospecting in the area here discussed has been carried on in three different coal-bearing beds, which, in descending order, are as follows:

1. The Evanston formation, in which the coals resemble the Evanston and Almy coals of southwestern Uinta County.

2. The Adaville formation, containing coals of uppermost Montana and lower Laramie age.

3. The Frontier formation, containing the Kemmerer, Willow Creek, and lower coals of Benton age.

The oldest rocks in which commercial coal was observed in this field are of Benton age. The Frontier is the important coal-bearing formation, and the coals it contains resemble very closely the Frontier and Cumberland coals of southern Uinta County. Bituminous shale and thin streaks of coal were also observed in the Bear River formation, but no coal of commercial value was seen.

As soon as railroad facilities can be obtained, which at present seems but a few years distant, the coal fields of central and northern Uinta County will probably constitute an important factor in the coal production of the State. For many years Idaho has been supplied with coal principally from the Kemmerer, Diamondville, and Union Pacific mines, in southern Uinta County, Wyo. In busy seasons these mines have been severely taxed to furnish, even at high prices, sufficient coal to meet the demand of the sugar companies and smelting industries. By opening the coal beds in northern Uinta County, as good if not better coal than that of the southern part of the county can be obtained, and the cost of transportation to northern Wyoming and southeastern Idaho can be greatly reduced. These coals are discussed briefly in the following pages, and the approximate outcrop and distribution of the coal-bearing beds are shown in Pl. XIII (p. 212).

KEMMERER, WILLOW CREEK, AND OTHER COALS OF BENTON AGE.

The beds containing the coals of Benton age outcrop throughout the area between Meridian Ridge and the Wyoming Range on the east and Absaroka Ridge and the Salt River Range on the west, in the Lazeart–John Day River syncline, and also between the Hoback and Wyoming ranges, north of Thompson Plateau, in the Lander syncline. In both of these localities the westward extension of the coal-bearing beds terminates against a fault that extends along the east base of the Salt River Range, Absaroka Ridge, and the Wyoming Range. It is not known whether all the coal-bearing formations mentioned in the preceding section extend throughout the field or not, but they are present in the southern part, and they or their equivalents may be found in other parts as further development work progresses. During the present survey most of the coal data could be obtained only from surface exposures or from shallow pits dug a few feet below the surface. The location of these pits and prospects is shown on the accompanying map (Pl. XIII). They are numbered consecutively from 1 to 88, according to township, range, and section, beginning at the southeast corner of the field.

COAL-BEARING BEDS IN THE LAZEART-JOHN DAY RIVER SYNCLINE.

The first important mine to tap the coal beds in the Lazeart syncline was that opened by the Diamond Coal and Coke Company at Diamondville, about 7½ miles south of the south boundary of this area, in 1894. Subsequently mines were opened by the same company at Glencoe and Oakley. In 1897 the mines at Frontier, 5 and 6 miles south of the boundary of this area, were opened by the Kemmerer Coal Company, and in 1900 the Cumberland mines were opened by the Union Pacific Coal Company. These mines and the occurrence of coal in southern Uinta County have been described elsewhere by A. C. Veatch.[a] All these mines developed the main Kemmerer bed, which lies above the Oyster Ridge sandstone. In the mine workings this coal bed ranges in thickness from 5 to 20 feet. At the Frontier mine two other beds have been opened, and one of them, known as the "A" bed, is worked. This coal bed, which lies 35 feet vertically below the main coal bed, is 6 feet thick and has a thin parting about 1 foot from the top. The quality of the coal is about the same as in the main bed. One analysis has been made of this lower coal.[b] About 10 feet vertically below the A bed is another known as the "B" bed. The coal is 6½ feet thick, with a thin parting 17 inches from the top. The intervening material between the A and B beds is a shale too soft to allow working the coal in bed B.

Shortly after opening the mines at Frontier, the Kemmerer Coal Company spent several years in prospecting the coal beds north of that place, on Willow Creek, in an effort to find coking coal. Beside prospecting the coals of the main Kemmerer group some work was also done in the coal beds below the Oyster Ridge sandstone.

The Willow Creek coal is about 550 feet below the main Kemmerer coal and 200 feet below the Oyster Ridge sandstone. In the SW. ¼ NW. ¼ sec. 19, T. 22 N., R. 115 W., where considerable coal was taken out, the bed is 3 feet thick; farther north, in the SW. ¼ SW. ¼ sec. 6, T. 22 N., R. 115 W., where the Kemmerer Coal Company proposes to open a mine, this bed reaches a thickness of 5 feet 8 inches. At both of these prospects small engines were installed and slopes were opened. In 1904 the two places together produced 3,000 tons of coal and about 750 tons of coke were shipped. Since then no development work has been done on the Willow Creek coals, but it is reported to be the intention of the Kemmerer Coal Company to develop this coal in the near future for its coking value. Tests show that the coal yields a coke of fair quality.

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[a] Coal and oil in Uinta County, Wyo.: Bull. U. S. Geol. Survey No. 285, 1906, pp. 331-353; Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: Prof. Paper U. S. Geol. Survey, No. 56.

[b] Veatch, A. C., Coal and oil in southern Uinta County, Wyo.: Bull. U. S. Geol. Survey No. 285, 1906, p. 339, analysis No. 8.

Two other prospects have been opened in the Willow Creek horizon, one in the NE. ¼ NW. ¼ sec. 2, T. 23 N., R. 116 W., by Walter C. Wright; the other in the NE. ¼ SE. ¼ sec. 16, T. 25 N., R. 115 W., by Howard M. Holden. At both of these places coal has been taken out for local ranch use. North of Holden's prospect no pits have been opened, and as the country is well covered with timber and exposures are rare, the coal outcrops are seen at few places. Several outcrops were observed at various places as far north as Snake River.

Several prospect pits have been opened in T. 22 N., R. 115 W., along the outcrop of the beds below the Willow Creek coal. The Spring Valley horizon, which is near the base of the Frontier formation, is approximately 1,500 feet stratigraphically below that of the main Kemmerer coal bed, and the Carter coal is approximately 200 feet higher than the Spring Valley bed. These horizons have not been prospected in this locality, and as the beds are everywhere covered by weathered surface material, the coal here, as well as farther south, is not readily seen. As a rule careful prospecting by digging pits or sinking diamond-drill holes is necessary in order to locate the beds. Even when a pit has been opened and a section of the coal exposed, the next year may find all traces of it obliterated and the pit deeply buried by débris from a landslide.

COAL-BEARING BEDS IN THE LANDER SYNCLINE.

The coal beds in the syncline between the Wyoming and Hoback ranges can not be directly correlated with any particular bed in the Lazeart-John Day River syncline. The prominent sandstone that forms Oyster Ridge and serves as a horizon marker is not present in this field, or if present has lost its ridge-making characteristics. The coal-bearing formation is the same and the coals so far as studied resemble very closely the Frontier and Willow Creek coals. A mine was opened in 1906 by Sam Smith east of McDougal Mountain, in unsurveyed territory, the location of which, if subdivided, would be in the SW. ¼ SW. ¼ sec. 33, T. 34 N., R. 115 W. A drift has been run along the strike for a distance of 20 feet, and several loads of coal have been hauled from the mine. A road has been built for this purpose, and it is the intention of Mr. Smith to supply coal to the ranchers in the Green River basin. The coal is of high grade and the bed is 6 feet 2 inches thick.

Farther north, east of the Wyoming Range and near the headwaters of Willow Creek, a tributary of Fall River, some prospecting has been done, but most of the pits have been buried beneath landslide material so that the coals can not be examined without reopening the pits. In the SE. ¼ NW. ¼ sec. 4, T. 36 N., R. 115 W., where

the greatest amount of development work has been done, a drift has been run 100 feet and a 6-foot coal bed with three partings has been opened. The analysis of the coal shows it to be the best coal in Uinta County thus far analyzed. The same coal extends northwestward across Snake River, but no study was made of the formations in that region.

ADAVILLE AND TWIN CREEK COALS.

The beds containing the Adaville and Twin Creek coals also lie in the Lazeart syncline, but occur only in its southern part. Since the discovery of these coals in 1876 by Smith and Bell Brothers,[a] who opened in the region of Hodges Pass, on the divide between Twin Creek and Hams Fork, twenty-nine beds of coal ranging in thickness from 1½ to 48 feet and aggregating 315 feet,[b] this coal-bearing formation has been noted for the great number and thickness of its beds. At the Adaville mine, in the NE. ¼ SW. ¼ sec. 20, T. 21 N., R. 116 W., one bed reaches a maximum thickness of 84 feet, with a single parting of clay 2 inches thick.

On account of the rising and pitching of the Lazeart syncline, the beds of this group occupy three basins in southern Uinta County, the northern part of the northernmost basin being shown on the map accompanying this report. Farther north the pitching of the syncline again brings in these beds, and the fourth basin in the series occurs on South Fontenelle Creek. Very little prospecting has been done on the coal beds north of Hams Fork, and thus far only one prospect pit has been opened in the fourth basin, namely, in the SW. ¼ SW. ¼ sec. 17, T. 25 N., R. 115 W., where 3 feet of coal occur under a bed of shale. The base of the coal bed was not seen. This group of coal beds contains a large amount of fuel of a fair quality which will undoubtedly be developed in the near future. The coal is clean and compact, having a bright luster and breaking with a conchoidal fracture, but it crumbles badly on exposure to the air.

COAL BEDS OF LABARGE MOUNTAIN AND FALL RIVER BASIN.

The coals on Labarge Mountain are in the Adaville formation, and those along Fall River are in the Evanston; the coal resembles the Evanston and Almy coals of southwestern Uinta County. Along the east side of Labarge Range several prospect pits have been opened in the Labarge Mountain coal beds, and in two localities coal is being mined for local ranch use. At Sayle's mine, in the SE. ¼ NW. ¼ sec. 7, T. 26 N., R. 113 W., an entry 180 feet long has been

[a] Peale, A. C., Report on the geology of the Green River district: Eleventh Ann. Rept. U. S. Geol. and Geog. Survey Terr. for 1877, p. 535.

[b] Veatch, A. C., Coal and oil in southern Uinta County, Wyo.: Bull. U. S. Geol. Survey No. 285, 1906, p. 337.

driven along the strike of the coal bed, which is here from 5½ to 6 feet thick. As a whole the coal is not good for forge use; by careful selection, however, certain parts of the bed yield a coal which will answer for this purpose. The coal comes from the mine in fair-sized blocks, but slacks readily on exposure to air, breaking with a conchoidal fracture. The coal is used by the neighboring ranchers for fuel, but because it slacks so quickly only small quantities are bought at a time. Near the north end of the Labarge Range, on the east side, a mine has been opened by Mr. Griggs in the SE. ¼ SE. ¼ sec. 12, T. 28 N., R. 114 W., where 8 feet of coal are exposed without reaching the base of the bed. The coal at this mine is of the same quality as that at the Sayle mine. It is mined only as the near-by ranchers are in need of it. Several prospect pits have been opened between these two mines, as well as north of the Griggs mine. At a number of places from seven to ten beds of coal ranging in thickness from 1 to 5 feet have been examined, and the entire formation shows numerous coal beds. The location of prospect pits and mines is shown on the accompanying map (Pl. XIII, p. 212). The sections of the coal beds at the various prospect pits are recorded in the table on pages 224–229.

In the Fall River basin practically no prospect pits have been dug and knowledge of the coal beds is therefore restricted entirely to surface exposures and bank diggings. These are few in number, inasmuch as throughout most of this area a heavy covering conceals the coal outcrops. Besides the prospects or surface diggings shown on Pl. XIII, coal prospects have been opened and reported on Cliff, Granite, and Shoal creeks by ranchers and prospectors, but these pits were opened some time ago and have since been deeply buried by landslips, so that the coal was not seen.

SECTIONS OF THE COALS.

The location of the various prospect pits that were examined or made during this survey, together with a section of the coal beds, is given in the subjoined table. The mines, prospect pits, and surface diggings are arranged by township, range, and section, being numbered consecutively from 1 to 88, beginning at the southeast corner of the field. The numbers agree with those used on Pl. XIII. The data for prospect pits in T. 22 N., Rs. 115 and 116 W., south of this area, have been added, as some of these have not previously been published. These pits are designated by letters in the table, so as not to interfere with the numbers used on the map.

Numerous test pits have been opened in the coal beds of the Frontier formation, a less number in the Adaville formation, and still less in the Evanston formation. The results of these tests are presented in the following table under numbers corresponding to those

used on the map. Some of the surface outcrops are not here listed. In the following table Nos. 25 and 39 are located on Carboniferous beds; No. 60 on Bear River beds; Nos. 1, 38, 41, 43, and 47–56, inclusive, on Adaville beds; Nos. 85, 86, and 88 on Evanston beds, and all the remainder on Frontier beds.

Sections of coal beds in central Uinta County, Wyo.

No. on Pl. XIII.[a]	Location. T.	R.	Sec.	Geologic formation.	Section.	Ft.	in.	Remarks.
1	22	115	6, NW. ¼ NW. ¼.	Frontier.	Shale.....		2	Willow Creek group; prospect pit.
					Coal.....	3	5	
					Shale.....		3	
					Coal.....	4	1	
					Shale.			
2	22	115	6, NW. ¼ NW. ¼.	Frontier.	Coal.....	2	4	Willow Creek group; prospect pit.
					Shale.....		8	
					Coal.....	2	6	
					Shale.			
3	22	115	6, NW. ¼ NW. ¼.	Frontier.	Shale.....	2		Willow Creek group; prospect pit.
					Sandstone		2	
					Coal (clay parting).		6	
					Shale.....	2	2	
					Coal.....	2	8	
					Shale.....	1	2	
					Coal.....	2	7	
					Shale.			
4	22	115	6, SW. ¼ NW. ¼.	Frontier.	Coal.....	5	8	Willow Creek group; prospect pit.
					Shale.			
[b] 5	22	115	6, SW. ¼ SW. ¼.	Frontier.	Sandstone		6	Willow Creek bed; coal and coke shipped rom this point in 1904.
					Coal.....	5	8	
					Shale.			
6	22	115	7, SE. ¼ NW. ¼.	Frontier.	Coal.....	4	5	W llow Creek bed; prospect pi
					Shale.			
7	22	115	7, SE. ¼ SE. ¼.	Frontier.	Shale.			Below Willow Creek bed prospect pit.
					Coal.....	3		
8	22	115	NE SW	Frontier.	Coal.....	4	4	Willow Creek bed
					Shale.			
9	22	115	18, NE. ¼ NW. ¼.	Frontier.	Coal.....	3	8	Wi low Creek bed
10	22	115	18, NE. ¼ NW. ¼.	Frontier.	Coal.....	4		Willow Creek bed.
A	22	115	18, SW. ¼ SE. ¼.	Frontier.	Coal.....	2	6	Below Wi low Creek bed; surface diggings.
B	22	115	19, NW. ¼ NE. ¼.	Frontier.	Coal.....	2	6	Below W llow Creek bed; surface diggings.
C	22	115	19, NW. ¼ NW. ¼.	Frontier.	Coal.....	3	2	Wi low Creek bed
[c] D	22	115	19, SW. ¼ NW. ¼.	Frontier.	Coal.....	3		Wi ow Creek bed small mine; some coal and coke was shipped from this place in 1904.
E	22	115	19, NW. ¼ SW. ¼.	Frontier.	Coal.....	3	2	Wi ow Creek bed.
F	22	115	30, NW. ¼ NW. ¼.	Frontier.	Sandstone		8	Willow Creek bed; prospect pit.
					Coal.....	4	5	
					Clay.....		8	
					Sandstone.			

[a] Letters in this column refer to prospect pits south of the area mapped.
[b] This coal is identical with that from prospect D. For analysis, see p. 236.
[c] For analysis of coal see p. 236.

Sections of coal beds in central Uinta County, Wyo.—Continued.

No. on Pl. XIII.[a]	Location. T.	R.	Sec.	Geologic formation.	Section.	Remarks.
					Ft. in.	
G	22	115	30, SE. ¼ SW. ¼.	Frontier.	Clay..... 1 Coal..... 4 10 Shale.	Willow Creek group; prospect pit.
11	22	116	1, NW. ¼ SW. ¼.	Frontier.	Coal..... 6	Kemmerer group.
12	22	116	1, NE. ¼ SW. ¼.	Frontier.	Coal..... 4	Kemmerer group.
13	22	116	1, SE. ¼ SW. ¼	Frontier.	Coal..... 8	Kemmerer group.
14	22	116	12, NE. ¼ NW. ¼.	Frontier.	Coal..... 4	Kemmerer groups; three prospects along strike of bed.
15	22	116	13, NW. ¼ NE. ¼.	Frontier.	Coal..... 8	Kemmerer group.
16	22	116	13, SW. ¼ NE. ¼.	Frontier.	Coal..... 8	Kemmerer group.
H	22	116	13, SW. ¼ SE. ¼	Frontier.	Coal..... 3	Kemmerer group.
I	22	116	21, NE. ¼ NW. ¼.	Adaville.	Coal..... 18	Adaville beds.
J	22	116	24, NW. ¼ NE ¼.	Frontier.	Coal..... 4	Kemmerer group.
K	22	116	24, NW. ¼ NE. ¼.	Frontier.	Coal..... 4	Kemmerer group; near southwest corner of tract.
L	22	116	24, SW. ¼ NE. ¼.	Frontier.	Coal..... 4 6	Three beds of Kemmerer group have been exposed at this prospect.
M	22	116	24, SE. ¼ NW. ¼.	Frontier.	Coal..... 3	Kemmerer group; two prospects opened in this 40-acre tract.
N	22	116	24, SW. ¼ SE. ¼.	Frontier.	Coal..... 4 6	Kemmerer group.
O	22	116	25, NW. ¼ NE. ¼.	Frontier.	Coal.	Kemmerer group.
P	22	116	25, NE. ¼ SW. ¼.	Frontier.	Coal.	Kemmerer group.
Q	22	116	25, SE. ¼ SW. ¼.	Frontier.	Coal.	Kemmerer group.
R	22	116	36, SE. ¼ NW. ¼.	Frontier.	Coal.	Kemmerer group.
S	22	116	36, NE. ¼ SW. ¼.	Frontier.		Kemmerer group.
T	22	116	36, SE. ¼ SW. ¼.	Frontier.		Kemmerer group; near center of tract.
U	22	116	36, SE. ¼ SW. ¼.	Frontier.		Kemmerer group; near southeast corner of tract.
V	22	116	36, SW. ¼ SE. ¼.	Frontier.		Kemmerer group; near southwest corner of tract.
17	23	115	6, lot 4.	Frontier.	Coal..... 2 Shale. Coal..... 2 4	Willow Creek group; two prospect pits opened.
18	23	115	7, lot 6.	Frontier.	Coal..... 1 6 Shale..... 2 Coal..... 3 Shale..... 1 Coal..... 3 3 Shale..... 5 Coal..... 2 1 Shale..... 2 Coal..... 1 2 Shale.	Willow Creek group; prospect pit near northeast corner of lot.

[a] Letters in this column refer to prospect pits south of the area mapped.

Sections of coal beds in central Uinta County, Wyo.—Continued.

No. on Pl. XIII.	Location. T.	R.	Sec.	Geologic formation.	Section.	Ft.	In.	Remarks.
19	23	115	7, lot 6.	Frontier.	Coal.....	1	6	Willow Creek group; prospect pit near south center of lot.
					Shale.....		2	
					Coal.....		3	
					Shale.....		1	
					Coal.....	3	3	
					Shale.....	5		
					Coal.....	2	1	
					Shale.....		2	
					Coal.....	1	2	
					Shale.			
20	23	115	18, lot 16.	Frontier.	Coal.....	1	3	Willow Creek group; prospect pit near south center of lot.
					Shale.....		2	
					Coal.....		3	
					Shale.....		1	
					Coal.....	3	8	
					Shale.....	5		
					Coal.....	2	2	
					Shale.....		2	
					Coal.....	1	2	
					Shale.			
21	23	115	19, lot 16.	Frontier.	Coal.....	2	2	Willow Creek group; prospect pit near south center of lot.
					Clay.....	2	6	
					Coal.....	1	4	
					Shale.....		2	
					Coal.....		3	
					Shale.....		1	
					Coal.....	3	5	
					Shale.....	1	4	
					Coal.....	3	2	
					Clay.....		2	
					Coal.....		10	
					Shale.			
22	23	115	31, lot 16.	Frontier.	Coal.....	1	10	Willow Creek group; prospect pit in west part of lot.
					Clay.....	3	8	
					Coal.....	2	9	
					Sandstone	1	8	
					Coal.....		8	
					Shale.			
[a] 23	23	116	2, SE. ¼ NW. ¼.	Frontier.	Sandstone, white.			Willow Creek group. Coal is mined at this place for ranch use.
					Shale.....	3		
					Coal.....	6	5	
					Shale.			
24	23	116	2, SW. ¼ SW. ¼.	Frontier.	Coal.			Willow Creek group, in northwest corner of tract.
25	23	116	9 SE. ¼ SE. ¼.	Park City (Carboniferous).	Shale, bituminous.			Not fully prospected; pits opened by sheepherders.
26	23	116	10, NW. ¼ SE. ¼.	Frontier.	Coal.			Willow Creek group; three coal beds have been opened in this tract.
27	23	116	10, SW. ¼ SE. ¼.	Frontier.	Coal.			Willow Creek group.
28	23	116	12, SW. ¼ SE. ¼.	Frontier.	Coal.....	4		Kemmerer group.
29	23	116	15, SW. ¼ NE. ¼.	Frontier.	Coal.....	4	3	Kemmerer group.
30	23	116	15, NE. ¼ NW. ¼.	Frontier.	Shale.			Willow Creek group.
					Coal.....	3	2	
					Shale.			
31	23	116	15, SW ¼ NW. ¼.	Frontier.	Coal.....	3	8	Willow Creek group; two prospects opened in this tract.
32	23	116	16, SE. ¼ SE. ¼.	Frontier.	Coal.....	4	2	Willow Creek group; surface diggings.

[a] For analysis of coal see pp. 232, 236.

Sections of coal beds in central Uinta County, Wyo.—Continued.

No. on Pl. XIII.	Location. T.	R.	Sec.	Geologic formation.	Section.	Ft.	in.	Remarks.
33	23	116	21, NE. ¼ NE ¼	Frontier.	Coal.....	3	6	Willow Creek group.
34	23	116	22, NW. ¼ NW. ¼.	Frontier.	Shale. Coal.....	4	3	Kemmerer group; surface diggings.
					Shale.			
35	23	116	36, SW. ¼ SW. ¼	Frontier.	Coal.....	8		Kemmerer group; prospect near southeast corner of tract.
36	24	115	19, lot 5.	Frontier.	Coal.....	3		Kemmerer group.
37	24	115	31, lot 18.	Frontier.	Coal.....	1	8	Willow Creek group; southeast corner of lot.
					Clay, fine.	3	7	
					Coal.....		9½	
					Bone.....		2	
					Coal.....		3	
					Bone.....		1	
					Coal.....	3	2	
					Sandstone	8		
					Coal.....	1	10	
					Shale.....		2	
					Coal.....	1	2	
					Sandstone.			
38	24	116	24, NE. ¼ SW. ¼.	Adaville....	Coal.....	3		Surface digging.
39	24	116	27, SW. ¼ NE. ¼	Park City (Carboniferous).	Shale, bituminous.			Not fully prospected.
[a] 40	25	115	16, NE. ¼ SE. ¼.	Frontier.	Shale. Coal.....	4	3	Willow Creek bed. Some coal mined here for ranchers' use.
					Shale.			
[a] 41	25	115	17, SW. ¼ SW. ¼	Adaville.	Shale. Coal.....	3		Adaville group; surface diggings.
42	25	115	23, SE. ¼ SW. ¼.	Frontier.	Coal.....	3	2	Kemmerer group; prospect pit.
43	26	113	7, SW. ¼ NE. ¼.	Adaville.	Shale. Coal.....	3		Labarge Mountain coal beds; seven beds of coal noted at this point, ranging in thickness from 1 to 3 feet.
					Shale.			
[a] 44	26	113	7, SE. ¼ NW. ¼.	Adaville.	Shale. Coal.....	6		Labarge Mountain coal beds; mine, 180 feet in depth. Coal is mined here for ranch use. Several prospects made near here.
					Sandstone.			
45	26	116	1, SW. ¼ SE. ¼.	Frontier.	Shale. Coal.....	3	2	Kemmerer group; surface diggings.
					Shale.			
46	26	116	1, SW. ¼ SW. ¼.	Frontier.	Coal.....	3		Kemmerer group; exposure in west bank of Fontenelle Creek.
[a] 47	27	113	29, SW. ¼ NE. ¼.	Adaville.	Shale. Coal.....	3	6	Labarge Mountain coal beds; prospect pit.
					Shale.			
48	27	113	32, SE. ¼ SE. ¼.	Adaville.	Coal.....	4	2	Labarge Mountain coal beds; three prospect pits opened in this tract. There are here six coal beds ranging in thickness from 1 foot 6 inches to 4 feet 2 inches.
[a] 49	27	113	32, SE. ¼ SW. ¼.	Adaville.	Shale. Coal.....	8	3	Labarge Mountain coal beds; prospect pit. See No. 47.
					Shale.....	3	2	
					Coal.....	3		
					Shale.			

[a] For analysis of coal see pp. 232, 236, 237.

Sections of coal beds in central Uinta County, Wyo.—Continued.

No. on Pl. XIII.	Location. T.	R.	Sec.	Geologic formation.	Section.	Remarks.
					Ft. in.	
50	28	113	7 SW. ¼ SW. ¼.	Adaville.	Coal..... 2	Labarge Mountain coal beds; prospect pit.
a 51	28	114	1, NE. ¼ NW. ¼.	Adaville.	Sandstone, shary (fossils). Coal..... 2 4 Shale.	Labarge Mountain coal beds; prospect pit 350 feet east of No. 52.
52	28	114	1, NE. ¼ NW. ¼.	Adaville.	Shale. Coal..... 8 Shale.	Labarge Mountain coal beds; prospect pit 350 feet west of No. 51.
a 53	28	114	1, SW. ¼ NW. ¼.	Adaville.	Sandstone and shale. Coal..... 3 3 Shale.	Labarge Mountain coal beds; drift 210 feet long.
54	28	114	1, SE. ¼ SW. ¼.	Adaville.	Sandstone. Coal..... 4 2	Labarge Mountain coal beds; coal outcrop near crest of hill.
a 55	28	114	12, SE. ¼ SE. ¼.	Adaville.	Coal..... 4 2	Labarge Mountain coal beds; near northwest corner of tract.
a 56	28	114	12, SE. ¼ SE. ¼.	Adaville.	Shale. Coal..... 8	Labarge Mountain coal beds; mine opening 125 feet long. Coal mined here for ranch use.
57	31	115	24, SE. ¼ NE. ¼.	Frontier.	Coal..... 4	Reported by Mr. Springman, postmaster at Stanley, Wyo.
58	31	117	12, SW. ¼ SW. ¼.	Frontier.	Shale. Coal..... 3	Frontier coal; surface diggings.
59	32	115	10, lot 1.	Frontier.	Coal..... 2 8 Sandstone. 10 Coal..... 3	Frontier coal; surface diggings.
60	32	117	28, NE. ¼ SE. ¼.	Bear River.	Coal.	Coal reported at this place by old land survey. See surveyor's notes of 14th auxiliary guide meridian.
61	33	115	34, NE. ¼ SE. ¼.	Frontier.	Coal..... 1 2	Frontier coal; surface diggings.
a 62	33	115	34, SE. ¼ SE. ¼.	Frontier.	Sandstone. Coal..... 2 Shale.	Frontier coal; surface diggings.
63	34	115	16, NW. ¼ SE. ¼.	Frontier.	Coal..... 3	Frontier coal; surface diggings.
a 64	34	115	33, NW. ¼ SE. ¼.	Frontier.	Shale. Coal..... 6 2 Shale.	Frontier coal. Coal mined for ranch use in Green River basin; drift opened 20 feet.
a 65	34	116	2, NW. ¼ SE. ¼.	Frontier.	Shale. Coal.....10 2 (?)	Frontier coal; surface diggings.
66	34	116	11, NW. ¼ NE. ¼.	Frontier.	Shale. Coal..... 4 6 (?)	Frontier coal; surface diggings.
a 67	35	116	35, NE. ¼ NW. ¼.	Frontier.	Sandstone, white. Coal..... 6 (?)	Frontier coal; surface diggings; unsurveyed territory near southeast corner of tract.
a 68	35	116	35, NE. ¼ NW. ¼.	Frontier.	Sandstone. Coal..... 4 (?)	Frontier coal; surface diggings; unsurveyed territory near northwest corner of tract.
a 69	36	116	11, NW. ¼ NE. ¼.	Frontier.	Sandstone, white. Shale.....10 Coal..... 1 2 Shale..... 8 Coal..... 2 3 Shale.	Frontier coal; surface diggings; unsurveyed territory. This coal bed lies 85 feet stratigraphically below No. 70.

a For analysis of coal see pp. 232, 236, 237.

Sections of coal beds in central Uinta County, Wyo.—Continued.

No. on Pl. XIII.	Location. T.	R.	Sec.	Geologic formation.	Section.	Ft.	In.	Remarks.
a 70	36	116	11, NW. ¼ NE. ¼.	Frontier.	Sandstone. Coal Shale Coal Shale.	 2 1	 5 4	Frontier coal; surface diggings; unsurveyed territory. This coal bed lies 85 feet stratigraphically above No. 69.
a 71	36	116	11, SW. ¼ NE. ¼.	Frontier.	Coal	6		Frontier coal; unsurveyed territory; 100-foot drift opened; 6-foot coal bed has three partings, the total thickness of which is 18 inches.
a 72	36	118	John Day River.	Frontier.	Coal	3		Frontier coal.
a 73	37	115	32, NE. ¼ NE. ¼.	Frontier.	Coal	5	6	Frontier coal; upper 2 feet pure, clean coal; lower 3½ feet coal and shale. From coal bed just above No. 78.
74	37	115	32, SE. ¼ SW. ¼.	Frontier.	Coal	6		Frontier coal; surface diggings.
a 75	37	115	32, SE. ¼ SW. ¼.	Frontier.	Sandstone, white. Coal	 2	 6	Frontier coal; surface diggings.
76	37	115	32, SW. ¼ SW. ¼.	Frontier.	Coal	3		Frontier coal; surface diggings.
77	37	115	32, SW. ¼ SW. ¼.	Frontier.	Coal	7	6	Frontier coal; surface diggings.
a 78	37	115	33, NW. ¼ NW. ¼.	Frontier.	Coal	5	6	Frontier coal; lower 2 feet 8 inches fine, clean coal. Coal lies just below No. 73.
a 79	37	116	1, SW. ¼ SE. ¼.	Frontier.	Coal	3	6	Frontier coal; surface diggings; lower 15 inches dirty coal; upper 2 feet clean coal. Bed lies about 40 feet lower than No. 80.
a 80	37	116	1, SW. ¼ SE. ¼.	Frontier.	Coal	3	9	Frontier coal; this has a 7-inch parting and lies about 40 feet above No. 79.
81	37	116	1, NW. ¼ SE. ¼	Frontier.	Coal	4	6	Frontier coal; surface diggings.
82	37	116	1, NW. ¼ SE. ¼.	Frontier.	Coal	7	6	Frontier coal. Two prospects opened by G. B. Budd at this place.
83	37	116	1, W. ½ SE. ¼.	Frontier.	Coal	20		Frontier coal; surface diggings.
a 84	37	116	1, SW. ¼ SE. ¼.	Frontier.	Coal and bone Clay, white Coal Clay Coal.	1 1 3 	 6 1 	Frontier coal; prospect pit.
a 85	38	113	31, NW. ¼ NE. ¼.	Evanston.	Shale. Coal Shale.	 1 	 	Fall River coal beds; surface diggings.
a 86	38	113	31, NW. ¼ SE. ¼.	Evanston.	Shale. Coal Shale.	 3 	 	Fall River coal beds; surface diggings.
87	38	116	11, NW. ¼ SW. ¼.	Frontier.	Coal	2	3	Frontier coal; surface diggings.
a 88	40	116	34, SW. ¼ NE. ¼.	(?)	Shale. Coal Clay.	 1	 5	Probably same as Fall River coal beds; surface diggings along bank of Snake River.

a For analysis of coal see pp. 232, 236, 237.

QUALITY AND CLASSIFICATION OF COALS.

The coals in this field form two distinct classes. The best coals are comprised in the first class, which includes all the coals of the Frontier formation, of Benton (Cretaceous) age. The second and inferior class includes all the coals of the Adaville formation, of uppermost Montana and lower Laramie age, and those of the Evanston formation, of Tertiary or upper Laramie age.

The coals of the first class, which rank as high-grade bituminous, have much the same physical characteristics throughout the field and are remarkably uniform in their properties. They are black, moderately hard, and usually compact, and for the most part have a bright luster. As a rule they contain small partings of clay and shale and some irregular nodules of pyrite (sulphur balls). The coal as a rule is not so clean as the Adaville coal, but contains much less moisture. Generally the coal does not slack to any appreciable extent on exposure to the weather. In two localities the coking properties of these coals have been tested with fairly good results.

The coals of the second class rank as high-grade subbituminous.[a] They are black and fairly hard, have a bright luster, and break with a conchoidal fracture. When scratched the streak is a dark brown. The coal comes from the mines in fair-sized blocks, but slacks readily on exposure to the air, breaking into small irregular pieces. When a large block of coal is exposed to the air for a few hours the entire block is filled with small cracks owing to the large percentage of moisture given off.

Samples of coal for analysis were collected from the mines and prospect pits in this region. The samples were taken from a clean surface of the whole bed by cutting a channel 3 or 4 inches in width and of even depth so that an equal amount of coal was obtained from each unit of section. The coal so removed was placed on a clean surface and broken to lumps one-half inch or less in diameter and thoroughly mixed. The sample was then quartered and opposite quarters taken and remixed. This process of quartering, selecting, and mixing was continued until the sample was reduced to about 1 quart, which was then placed in a galvanized-iron can with a description of the coal and location of the mine, sealed, and shipped to the United States Geological Survey fuel-testing plant at St. Louis, Mo., for analysis. The sealed can reached the chemical laboratory with its moisture content unchanged. In order to determine the "loss of moisture on air drying," the following method was used:[b]

In order to make determinations of the loosely held moisture more uniform and definite, a special drying oven has been designed and introduced into the laboratory;

[a] The term subbituminous has been adopted by the Geological Survey for the class of coal usually designated "black lignite."

[b] Lord, N. W., Preliminary report on the operations of the fuel-testing plant * * * at St. Louis, Mo., 1905: Bull. U. S. Geol. Survey No. 290, 1906, pp. 29-30.

in this oven samples of several pounds weight can be dried in a gentle current of air raised from 10° to 20° above the temperature of the laboratory. In this way the coal is air dried in an atmosphere with a very low dew-point and not subject to large percentage variations, and the results obtained are considerably more concordant. Another advantage of this method is that it greatly shortens the time of air drying, so that the samples can be prepared in much less time than formerly.

In studying the table of analyses it should be borne in mind that most of the coal samples were collected from surface outcrops or shallow pits, and that the samples were weathered badly and more or less altered, having a high percentage of moisture, as it was not possible within the given time to open up a coal bed so as to get unaltered coal. In some cases where two samples were taken from the same horizon and from the same kind of coal, except that one was partially altered and the other not, the difference in the calorific power is from 2,000 to 3,000 British thermal units. Only eleven samples were obtained that represent fairly well the real values of the coals in their unaltered condition, namely, at localities Nos. 23, 40, 44, 49, 56, 64, 71, 73, 78, 79, and 80. All other samples were collected within the zone of alteration and give, to a greater or less degree, inferior results. No doubt the high percentage of moisture and oxygen in these samples is due in part to the altered condition of the coal. The air-drying loss of the samples is not entirely comparable. This likewise may be due in part to the physical conditions and the changes undergone during the process of weathering. In the following table the coal analyses have been arranged by townships, ranges, and sections, beginning at the southeast corner of the field. The numbers in the first column correspond with the numbers given in the table of sections and on the accompanying map (Pl. XIII, p. 212). The laboratory numbers are those given by the fuel-testing plant and will be used in its publications.

Analyses of samples of coal as received from mines and prospects in central Uinta County, Wyo.

No. on Pl. XIII.[a]	Where sample was collected.	Chemical analyses.														Sampler.
			Proximate.							Ultimate.				Heating values.		
		Laboratory No.	Moisture after air drying.	Air-drying loss.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. T. U.	
23	Mine shallow	3572	4.36	2.50	6.88	38.05	51.52	3.55	1.76	5.28	70.62	0.99	17.80	7,051	12,692	A. R. Schultz.
40	Prospect pit	3570	3.84	3.90	7.74	34.65	53.31	4.30	.46	5.33	71.51	1.13	17.27	7,051	12,692	B. A. Iverson.
41	do	3696	9.05	16.50	25.55	33.82	37.61	3.02	.41	5.80	49.29	.94	40.54	4,507	8,113	H. C. Schleuter.
44	Mine, 180-foot drift	3698	10.22	12.70	22.92	34.46	40.14	2.48	.73	6.37	55.71	.94	33.77	5,463	9,833	E. E. Smith, A. R. Schultz.
47	Surface pit	3697	9.72	19.30	29.02	31.34	31.72	7.92	1.35	5.43	38.61	.79	45.90	3,422	6,160	B. A. Iverson.
49	Prospect pit	3693	10.78	11.60	22.38	35.77	38.84	3.01	1.86	6.36	54.60	.91	33.26	5,354	9,637	A. R. Schultz, E. E. Smith.
51	do	3695	13.10	22.60	35.70	28.85	28.02	7.43	.58	6.31	37.16	.87	47.65	3,247	5,845	A. R. Schultz.
53	Prospect tunnel, 210 feet long	3700	9.46	18.10	27.56	31.00	31.77	9.67	.90	5.69	40.46	1.05	42.23	3,667	6,601	Do.
55	Prospect pit	3694	10.88	21.30	32.18	30.81	31.60	5.41	.48	5.87	38.29	.67	49.28	3,516	6,328	Do.
56	Mine, drift 125 feet long	3699	9.02	10.60	19.62	32.71	42.51	5.16	1.02	6.00	55.47	.97	31.38	5,399	9,718	A. R. Schultz, E. E. Smith.
62	Surface	3778	8.52	5.50	14.02	34.00	49.06	2.92	.60	5.36	61.25	1.51	28.36	6,011	10,820	E. E. Smith.
64	Mine, 20-foot drift	3891	6.50	3.10	9.60	38.71	46.92	4.77	.32	5.49	66.93	1.34	21.15	6,666	11,999	A. R. Schultz.
65	Surface	3890	8.48	12.80	21.28	34.84	39.27	4.61	.24	5.69	53.73	1.16	34.57	5,035	9,063	Do.
67	do	4004	10.03	10.40	20.43	30.65	42.43	6.49	.42	5.79	53.23	1.30	32.77	5,048	9,086	W. H. Longhurst.
68	do	4000	9.99	17.20	27.19	30.30	34.54	7.97	.94	5.89	44.67	1.08	39.45	4,176	7,517	Do.
69	do	4005	10.90	10.70	21.60	29.16	42.34	6.90	.99	5.49	53.04	1.07	32.51	4,962	8,932	A. R. Schultz.
70	do	4001	3.91	3.00	6.91	31.91	51.86	9.32	1.54	5.01	65.52	1.01	17.60	6,373	11,471	Do.
71	Tunnel, 100-foot drift	4299	2.37	1.30	3.67	36.30	56.59	3.44	.70	5.66	77.17	.84	12.19	7,613	13,703	J. G. Hawkins.
72	Surface	4323	4.20	3.60	7.80	36.25	54.33	1.62	.27	5.35	70.34	1.43	20.99	7,093	12,767	J. D. Livingston.
73	Prospect pit	4300	1.89	1.60	3.49	35.90	50.59	10.02	.92	5.09	69.67	1.01	13.29	7,150	12,870	J. G. Hawkins.
75	do	4006	8.66	5.70	14.36	32.48	48.73	4.43	3.56	5.33	60.67	1.30	24.71	5,724	10,303	E. E. Smith
78	do	4303	1.99	3.50	5.49	35.88	55.51	3.12	.91	5.26	74.15	1.26	15.30	7,539	13,570	J. G. Hawkins.
79	do	4302	4.51	2.30	6.81	33.42	53.59	6.18	.62	4.81	69.45	1.52	17.42	6,752	12,155	Do.
80	do	4301	4.70	6.00	10.70	30.67	54.35	4.28	.78	5.34	66.18	1.45	21.97	6,357	11,443	Do.
84	do	4003	5.46	4.60	10.06	32.94	53.30	3.70	.38	5.27	66.94	1.29	22.42	6,464	11,635	E. E. Smith.
85	Surface	3892	10.32	8.70	19.02	39.68	27.83	13.47	2.60	5.26	48.01	1.28	29.38	4,662	8,392	A. R. Schultz.
86	do	3893	12.21	4.30	16.51	32.67	37.57	13.25	4.35	5.15	49.38	.99	26.88	4,757	8,563	Do.
88	do	4002	10.37	7.90	18.27	23.19	34.46	24.08	.30	4.12	42.03	.57	28.90	3,693	6,647	H. C. Schleuter.

[a] For location, geologic formation, name of coal bed, and thickness of coal, see table of sections, pp. 224-229.

In order that the analyses of the Uinta County coals may be compared with those of other coals from the Rocky Mountain region, the subjoined table has been prepared. The analyses are separated into groups according to the geologic horizons of the coals. The analyses have been calculated on the basis of the air-dried sample and arranged according to the calorific values as expressed in British thermal units. The ash and sulphur, although accidental impurities varying greatly from place to place in the same bed, are of considerable commercial importance, and it has therefore seemed better to retain these impurities rather than to calculate the analyses on the basis of air-dried ash-free samples. The carbon-hydrogen ratio proposed by M. R. Campbell[a] in 1905 and the carbon-oxygen ratio are given for comparison. The table includes also the ultimate analyses of the ten coal samples collected by A. C. Veatch and party during the summer of 1905 in southern Uinta County, as well as those of the two mine samples and one carload sample collected in 1906 at Adaville, a few miles west of Kemmerer, by inspectors of the Geological Survey fuel-testing plant.

[a] The classification of coals: Trans. Am. Inst. Min. Eng., Washington meeting, May, 1905; Prof. Paper U. S. Geol. Survey No. 48, 1906, pp. 156-173.

Analyses of air-dried samples of Uinta County coals.

FRONTIER COALS OF BENTON AGE.

No. in table of sections (pp. 224-229).	Place.	Location. T.	Location. R.	Location. Sec.	Coal bed.	Thickness of coal. Ft.	Thickness of coal. in.	Where sample was collected.	Sampler.
78	Willow Creek	37	115	33, NW. ¼ NW. ¼	Frontier group	5	6	Prospect pit	J. G. Hawkins.
71	do	36	116	11, SW. ¼ NE. ¼	do	6	0	Tunnel, 100 feet	Do.
aD	Oyster Ridge	22	115	19, SW. ¼ NW. ¼	Willow Creek	3	0	Prospect mine	Max A. Pishel.
72	John Day River				Frontier group			Surface	J. D. Livingston.
40	Oyster Ridge	25	115	16, NE. ¼ SE. ¼	Willow Creek group	4	3	Prospect mine	B. A. Iverson.
(a)	Hams Fork	21	116	25, NE. ¼ NW. ¼	Main Kemmerer	7	0	Mine	Max A. Pishel.
73	Willow Creek	37	115	32, NE. ¼ NE. ¼	Frontier group	5	6	Prospect pit	J. G. Hawkins.
(a)	Hams Fork	21	116	12, SE. ¼ NW. ¼	Kemmerer seam A	6	0	Mine	Max A. Pishel.
23	Mammoth Hollow	23	116	2, SW. ¼ SW. ¼	Willow Creek group	6	5	Prospect mine	A. R. Schultz.
(a)	Hams Fork	21	116	12, SE. ¼ NW. ¼	Main Kemmerer	9	0	Mine	Max A. Pishel.
(a)	Cumberland	19	116	31, NE. ¼ SW. ¼	do	8	0	do	Do.
79	Willow Creek	37	116	1, SW. ¼ SE. ¼	Frontier group	3	6	Prospect pit	J. G. Hawkins.
64	McDougals Mountain	34	115	33, NW. ¼ SE. ¼	do	6	2	Prospect mine, 20-foot drift	A. R. Schultz.
84	Willow Creek	37	116	1, SW. ¼ SE. ¼	do	3	0	Prospect pit	E. E. Smith.
80	do	37	116	1, SW. ¼ SE. ¼	do	3	9	do	J. G. Hawkins.
70	do	36	116	11, NW. ¼ NE. ¼	do	3	4	Surface	A. R. Schultz.
(a)	Oyster Ridge	15	118	12, NW. ¼	Spring Valley group	4	0	Mine prospect	Max A. Pishel.
62	Lander Peak	33	115	34, SE. ¼ SE. ¼	Frontier group	2	0	Surface	E. E. Smith.
75	Willow Creek	37	115	32, SE. ¼ SW. ¼	do	2	6	Prospect pit	Do.
65	Wyoming Range	34	116	2, NW. ¼ SE. ¼	do	10	2	Surface	A. R. Schultz.
68	do	35	116	35, NE. ¼ NW. ¼	do	6	0	do	W. H. Longhurst.
69	Willow Creek	36	116	11, NW. ¼ NE. ¼	do	4	3	do	A. R. Schultz.
67	Wyoming Range	35	116	35, NE. ¼ NW. ¼	do	2	0	do	W. H. Longhurst.

ADAVILLE AND LABARGE MOUNTAIN COALS OF UPPER MONTANA AND LOWER LARAMIE AGE.

(b)	Mammoth Hollow	21	116	20, NE. ¼ SW. ¼	Adaville group	84	0	Mine (carload sample)	
(b)	do	21	116	20, NE. ¼ SW. ¼	do	84	0	Mine	
(b)	do	21	116	20, NE. ¼ SW. ¼	do	84	0	do	
(a)	do	21	116	20, NE. ¼ SW. ¼	do	84	0	do	Max A. Pishel.
(a)	do	15	118	8, SE. ¼ SW. ¼	do	30	0	do	Do.
41	do	25	115	17, SW. ¼ SW. ¼	do	3	0	Prospect pit	H. C. Schleuter.
44	Labarge Range	26	13	7, SE. ¼ NW. ¼	Labarge Mountain group	6	0	Mine, 180-foot drift	E. E. Smith, A. R. Schultz.
49	do	27	113	32, SE. ¼ SW. ¼	do	8	3	Prospect pit	Do.
56	do	28	114	12, SE. ¼ SE. ¼	do	8	0	Mine, 125-foot drift	Do.
53	do	28	114	1, SW. ¼ NW. ¼	do	3	3	Tunnel, 210 feet long	A. R. Schultz.
55	do	28	114	12, SE. ¼ SE. ¼	do	4	2	Prospect pit	Do.
47	do	27	113	29, SW. ¼ NE. ¼	do	3	6	Surface	B. A. Iverson.
51	do	28	114	1, NE. ¼ NW. ¼	do	2	4	Prospect pit	A. R. Schultz.

EVANSTON, ALMY, AND FALL RIVER COALS OF EVANSTON AGE.

(a)					Almy	24	0	Mine, 3,000-foot slope	Max A. Pishel.
(a)									Do.
85	Fall River	38	113	31, NW. ¼ NE. ¼	Fall River group	1	0	Surface	A. R. Schultz.
86	do	38	113	31, NW. ¼ SE. ¼	do	3	0	do	Do.
88	Snake River	40	116	34, SW. ¼ NE. ¼	(?)	1	5	do	H. C. Schleuter.

a Sample collected by A. C. Veatch and party in southern Uinta County in 1905.
b Sample collected by U. S. Geol. Survey fuel-testing plant in southern Uinta County in 1906.

Analyses of air-dried samples of Uinta County coals—Continued.

FRONTIER COALS OF BENTON AGE.

No. in table of sections (pp. 224-229).	Laboratory No.	Chemical analyses. Proximate. Per cent of moisture after air drying.	Air-drying loss.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heating values. Calories.	B. T. U.	Ratios. C/H	C/O
78	4303	1.99	3.50	2.06	37.18	57.53	3.23	0.94	5.04	76.84	1.31	12.64	7,812	14,062	15.23	6.08
71	4299	2.37	1.30	2.40	36.79	57.33	3.48	.71	5.59	78.19	.85	11.18	7,713	13,883	13.98	6.99
aD	2285	2.56	1.40	2.59	36.68	55.90	4.83	.78	5.09	77.11	1.33	10.86	7,607	13,694	15.15	6.50
72	4323	4.20	3.60	4.36	37.60	56.36	1.68	.28	5.14	72.97	1.48	18.45	7,358	13,244	14.18	3.95
40	3570	3.84	3.90	4.00	36.06	55.47	4.47	.48	5.10	74.41	1.18	14.36	7,336	13,207	14.60	5.11
(a)	2284	3.83	1.30	3.88	41.04	50.41	4.67	.50	5.56	73.91	1.20	14.16	7,297	13,130	13.29	5.22
73	4300	1.89	1.60	1.92	36.48	51.42	10.18	.93	4.99	70.81	1.03	12.06	7,266	13,079	14.19	5.87
(a)	2286	3.86	2.00	3.95	40.30	52.04	3.72	1.09	5.46	74.45	1.10	14.18	7,247	13,044	13.63	5.25
23	3572	4.36	2.50	4.49	39.03	52.84	3.64	1.81	5.12	72.43	1.02	15.98	7,231	13,017	14.14	4.53
(a)	2287	3.49	2.40	3.57	38.52	50.21	7.70	1.42	5.15	70.18	1.09	14.46	7,039	12,664	13.63	4.85
(a)	2245	4.18	2.60	4.29	40.85	48.69	6.17	.44	5.41	70.85	1.15	15.95	6,997	12,587	13.10	4.43
79	4302	4.51	2.30	4.62	34.20	54.85	6.33	.64	4.65	71.09	1.55	15.74	6,911	12,441	15.28	4.51
64	3891	6.50	3.10	6.71	39.95	48.42	4.92	.33	5.31	69.07	1.38	18.99	6,879	12,383	13.00	3.63
84	4003	5.46	4.60	5.72	34.52	55.88	3.88	.40	4.98	70.17	1.35	19.22	6,776	12,196	14.09	3.64
80	4301	4.70	6.00	5.00	32.63	57.82	4.55	.82	4.98	70.41	1.54	17.70	6,762	12,173	14.14	3.98
70	4001	3.91	3.00	4.03	32.89	53.46	9.61	1.58	4.83	67.54	1.04	15.40	6,569	11,825	13.98	4.38
(a)	2212	4.25	2.60	4.36	36.57	45.03	14.04	.96	4.83	65.61	1.15	13.41	6,473	11,652	13.58	4.82
62	3778	8.52	5.50	9.02	35.98	51.91	3.09	.63	5.02	64.83	1.60	24.83	6,361	11,450	12.90	2.61
75	4006	8.66	5.70	9.18	34.44	51.68	4.70	3.78	4.98	64.34	1.37	20.83	6,070	10,925	12.92	3.09
65	3890	8.48	12.80	9.73	39.95	45.03	5.29	.28	4.89	61.62	1.33	26.59	5,774	10,393	12.60	2.31
68	4000	9.99	17.20	11.19	34.21	47.36	7.24	.47	5.18	59.41	1.45	26.25	5,634	10,141	11.47	2.28
69	4005	10.90	10.70	12.20	32.65	47.42	7.73	1.10	4.83	59.39	1.20	25.75	5,556	10,002	12.27	2.30
67	4004	10.03	10.40	12.06	36.59	41.72	9.63	1.13	4.81	53.94	1.31	29.18	5,043	9,079	11.21	1.85

ADAVILLE AND LABARGE MOUNTAIN COALS OF UPPER MONTANA AND LOWER LARAMIE AGE.

(b)	3390	7.70	11.30	8.69	41.31	46.49	3.51	0.55	5.81	66.95	1.10	22.08	6,455	11,620	11.52	3.03
(b)	3203	10.28	10.60	11.50	40.17	45.46	2.87	.60	.....	.....	.....	.....	.....	.....	.....	.....
(b)	3202	10.37	10.20	11.55	40.44	45.08	2.93	.57	.....	.....	.....	.....	6,333	11,399	.....	.....
(a)	2283	7.57	14.80	8.88	40.49	47.20	3.43	.58	5.24	65.76	1.03	23.96	6,385	11,493	12.55	2.74
(a)	2211	12.45	6.70	13.34	33.43	41.58	5.65	1.26	5.77	67.12	1.08	25.12	6,035	10,864	10.59	2.43
41	3696	9.05	16.50	10.84	40.50	45.04	3.62	.49	4.75	59.03	1.13	30.98	5,398	9,716	12.42	1.95
44	3698	10.22	12.70	11.71	39.47	45.98	2.84	.84	5.68	63.81	1.08	25.75	6,258	11,263	11.23	2.40
49	3693	10.78	11.60	12.19	40.46	43.94	3.41	2.10	5.74	61.76	1.03	25.96	6,057	10,902	10.76	2.33
56	3699	9.02	10.60	10.09	36.59	47.55	5.77	1.14	5.39	62.05	1.09	24.56	6,039	10,870	11.51	2.52
53	3700	9.46	18.10	11.55	37.85	38.79	11.81	1.10	4.44	49.40	1.28	31.92	4,477	8,060	11.51	2.52
55	3694	10.88	21.30	13.83	39.15	40.15	6.87	.61	4.45	48.65	.85	38.57	4,468	8,042	10.93	1.26
47	3697	9.72	19.30	12.04	38.84	39.31	9.81	1.67	4.07	47.85	.98	35.62	4,240	7,633	11.76	1.34
51	3695	13.10	22.60	16.93	37.27	36.20	9.60	.75	4.91	48.01	1.12	35.61	4,195	7,551	9.77	1.34

EVANSTON, ALMY, AND FALL RIVER COALS OF EVANSTON AGE.

(a)	2325	7.73	6.70	8.29	39.45	44.52	7.74	0.22	4.97	64.28	1.23	21.56	6,220	11,197	12.93	2.98
(a)	2326	7.21	6.90	7.74	37.96	36.95	17.35	4.78	4.86	52.53	.88	19.60	5,261	9,469	10.81	2.68
85	3892	10.32	8.70	11.31	43.46	30.48	14.75	2.85	4.70	52.58	1.40	23.72	5,106	9,192	11.19	2.21
86	3893	12.21	4.30	12.75	34.14	39.26	13.85	4.55	4.88	51.59	1.03	24.10	4,971	8,948	10.57	2.14
88	4002	10.37	7.90	11.26	25.17	37.41	26.16	.33	3.51	45.63	.62	23.75	4,010	7,217	13.00	1.92

a Sample collected by A. C. Veatch and party in southern Uinta County in 1905.
b Sample collected by U. S. Geol. Survey fuel-testing plant in southern Uinta County in 1906.

On examining the foregoing table it will be observed that the Frontier coals, of Benton age, fall into groups G, H, and I of the classification proposed by Campbell.[a] Three of the samples collected last summer, namely, Nos. 73, 78, and 79, with the carbon-hydrogen ratio ranging from 14.6 to 15.28 per cent, and the Willow Creek coal, D of the table, collected in 1905, with a carbon-hydrogen ratio of 15.15 per cent, fall into group G of the bituminous class, which includes the Pittsburg coal and some of the high-grade coals of West Virginia, Kentucky, and Alabama. All the other samples except the last three (Nos. 67, 68, and 69) fall into group H of the bituminous class and compare favorably with the Indian Territory, Kansas, high-grade Illinois, Iowa, and Missouri, and second-grade Kentucky coals. The last three samples in the table fall into group I, not so much because they are inferior coals, but on account of the altered condition of the coal near the surface, where the samples were collected. If good samples of these coal beds had been obtained, they would unquestionably fall into group H and possibly some of them into group G. The sulphur content of these coals is low, being generally less than 1 per cent; the lowest is 0.28, the highest 3.78, and the average of the 23 analyses 0.93 per cent. The ash content ranges from 1.68 to 14.04 per cent, with an average of 6.12 per cent; the carbon ratios range from 53.98 to 78.19 per cent, with an average of 69.11 per cent.

The Adaville coals of Uinta County fall in part into the bituminous class and in part into the subbituminous class. According to the carbon-hydrogen classification, the chemical analyses place one of these coals in group H, five in group I, and four in group J. Group I, the lowest of the bituminous coals, includes the majority of Illinois, Iowa, Missouri, and Indiana coals and many of the Wyoming, Montana, and Colorado coals; group J includes all the subbituminous coals and lignites. The sulphur content of these coals is low, ranging from 0.49 to 2.10 per cent, with an average of 0.94 per cent for the thirteen samples. The ash ranges from 2.87 to 11.81 per cent, with an average of 5.55 per cent, or a little less than the amount of ash in the Frontier coals. The carbon content ranges from 47.85 to 66.95 per cent, with an average of 58.22 per cent for eleven samples.

The Evanston, Almy, and Fall River coals also fall into the bituminous and subbituminous classes. The chemical analyses place one of the coals in group H, one in group I, and three in group J. These coals contain more sulphur and ash than either the Frontier or the Adaville coals and a somewhat lower per cent of carbon. The sulphur ranges from 0.22 to 4.78 per cent, with an average of 2.55 per cent for five samples. The ash ranges from 7.74 to 26.16 per cent, with an average of 15.97 per cent for the five

[a] Campbell, M. R., Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, pp. 168-170.

samples. The carbon ranges from 45.63 to 64.28 per cent, with an average of 53.32 per cent.

The distinction between the Frontier (Benton) coals, on the one hand, and the Adaville, Labarge Mountain, and Fall River coals, on the other, is largely physical. The last two generally contain more moisture than the Frontier coals, have a lower calorific value, weather more readily on exposure to the atmosphere, and are lighter in weight. The most marked difference between the Frontier and the Adaville and Labarge Mountain coals consists in the rapidity with which the latter break down when exposed to weathering and the peculiar manner in which such breaks occur, the coal seeming to undergo a chemical change which is accompanied with a conchoidal or irregular fracture that does not conform in any way with bedding planes.

In making any comparison with the coals in another field, only 11 analyses (Nos. 4303, 4299, 3570, 4300, 3572, 4302, 3891, 4301, 3698, 3693, and 3699) of the samples collected last summer, together with those of the samples collected in southern Uinta County, should be taken as representative of the coals in their unaltered condition. When compared with the analyses made by the United States Geological Survey fuel-testing plant of samples collected in other parts of the Rocky Mountain region, it will be observed that the coals of Benton age found in Uinta County rank as high as the best bituminous coals in other fields and are much better than some of the Montana, Colorado, Utah, and New Mexico coals, which are about the same in character as the Adaville, Evanston, Labarge Mountain, and Fall River coals of Uinta County. The Benton coals of this county may be said to belong at the top of the group of the best bituminous coals of the Rocky Mountain region. The coals in group G are by far the best thus far prospected in this field. The high quality of these coals in part of central Uinta County is not the result of igneous intrusion, as is often held by local residents, and they are therefore apt to be of a uniform character over a large area. From the preliminary tests thus far made, some of the Benton coals rank as fairly good coking coals, and probably will in the near future be developed for their coking properties.

TRANSPORTATION.

No railroad crosses or enters this area, the nearest being the Oregon Short Line, which passes through Kemmerer, 6 miles south of the southern boundary, and then gradually gets farther away as it skirts the southern and western boundaries on its way to the Snake River valley. The St. Anthony branch of the Oregon Short Line lies about 80 miles west of the northwest corner of this district.

A stage leaves St. Anthony, Idaho, daily, except Sunday, via Teton Pass, for Jackson, Wyo., a distance of about 80 miles. The

stage carries mail and supplies to all the small stores and hamlets along the line.

From Kemmerer a stage leaves daily except Sundays for Pinedale, Wyo. This stage line crosses the southeastern part of this area and then skirts the eastern margin along Green River, passing Slate Creek, Palisade, Labarge, Midway, Big Piny, Ball, Daniel, and Burns. The stage carries mail and supplies to the small stores, hamlets, and ranches along the road, thus making Kemmerer the main supply station for all the upper Green River basin and the part of the Fall River basin lying east of the Hoback Range.

There are only three practical railroad routes across this country. The first and best passes south of Meridian and Absaroka ridges and was in part surveyed in 1886 by the Wyoming and Eastern Railway Company, the line going down Big Sandy River, thence across Green River near the mouth of Slate Creek, up that creek a short distance, crossing the southeast corner of this area in T. 22 N., Rs. 113 and 114 W., and connecting with the Oregon Short Line in the vicinity of Old Hams Fork a short distance west of Kemmerer.

A second route which has never been surveyed but which might be utilized at a large expense extends from Green River near the mouth of Labarge Creek, up that creek to a point near its headwaters, thence across the divide at the south end of the Salt River Range into Star Valley; or at a somewhat greater expense the eastern portion of the line might follow somewhat closely the Lander road. This, however, would necessitate another tunnel across the divide between South Piny and Labarge creeks.

It is not probable that a line will ever be built along either of these routes, for so far as the mineral deposits within the southern part of the district are concerned it would be more economical and much more serviceable to build a spur from the Oregon Short Line northward from Kemmerer, up Mammoth Hollow or Willow Creek, along the strike of the coal-bearing beds as far north as the headwaters of Fontenelle Creek or possibly Labarge Creek. A preliminary survey has already been made along this route as far north as the Willow Creek prospect, in the southern part of the district. The coals east of Meridian Ridge along the east base of Labarge Range could best be reached by a spur from some point on the Oregon Short Line or from some other line extending up Green River.

The third route follows Snake River across the northern part of the field and a railroad may soon be built along this line. Whether the line will be built through the northern part of this field, along Fall River, and cross the divide into the Green River basin, or pass north of the Gros Ventre Mountains to Buffalo Fork and connect with the Wyoming and Northwestern Railway, or extend up Gros Ventre

River, cross the Continental Divide, and continue eastward down Wind River, remains to be seen.

In 1890 the Nebraska and Wyoming Railroad Company made a survey along the Fall River route. The survey extended up Green River to the mouth of Middle Beaver Creek, thence up that stream, crossing the divide into the Fall River basin, and thence down Fall and Snake rivers into Idaho. The location of the portion of the line included in this area is shown on Pl. XIII (p. 212) by the single black line along Fall and Snake rivers. Although this involves a steep grade in crossing the divide between Fall and Green rivers, it would make a good road and be within a short distance of all the important coal deposits in the northern part of the area. It would cut directly across the coal-bearing formations on Fall and Snake rivers, and by a few spurs could readily reach all the coals east of the Wyoming Range, including those of Willow Creek, a tributary of Fall River, which rank as high as the Frontier, Willow Creek, and Cumberland coals of southern Uinta County. The coals of John Day River and its tributaries could probably be reached by way of John Day Canyon or by way of Bailey Creek west of the Wyoming Range.

In 1905 the Idaho and Wyoming Railway Company surveyed a line from Jackson, Wyo., down Flat Creek and Snake River, to connect with the St. Anthony branch of the Oregon Short Line just north of Idaho Falls, Idaho. The location of this line is shown on Pl. XIII by a single line along Snake River. If it is built it may be extended northward to connect with the Wyoming and Northwestern Railway near the mouth of Buffalo Fork. In the same year the Wyoming and Northwestern surveyed a line up Wind River and across the divide into Buffalo Fork, thence down that stream to Snake River, and up Snake River to the vicinity of the Yellowstone National Park. The completion of these two projected railroads, which by the most optimistic is expected within the next three or four years, will entirely alter the economic conditions in the northern part of this field, materially increase the population of Jackson Hole, and tend to make it popular as a summer resort as well as a center of mining activities.

If these railroads are completed, the coal fields in the northern part of this area will probably be rapidly developed, owing to the high quality of the coals and their nearness to the great smelting and sugar industries in the Salt Lake valley, the Snake River valley, Anaconda, and Butte. As soon as communication is established with outside markets lumbering will become an important industry in this area, and the abundance of timber in the vicinity of the coal deposits will tend to stimulate and develop coal prospecting and mining.

THE LANDER COAL FIELD, WYOMING.

By E. G. Woodruff.

A bed of coal in the sandstones of the Montana formation in central Wyoming has been worked to a moderate extent in the Popo Agie Valley 8 miles northeast of Lander, Fremont County. In this region the Montana formation consists of a lower member of shale several thousand feet thick and an upper member of sandstones, shales, and conglomerates between 500 and 600 feet thick. The shale has usually been regarded as the Pierre and the overlying sandstones have been supposed to represent the Fox Hills, but it is quite possible that the sandstones are equivalent to the Mesaverde of the Colorado section. The sandstones are extensively exposed on the east slope of a subordinate anticline on the east side of the Wind River uplift from a point due east of Lander to Little Wind River and beyond. To the south and in the greater portion of the Wind River valley they are covered by Tertiary deposits. The coal occurs about 250 feet above the base of the first sandstone, lying upon an irregular deposit of gray conglomerate. The dip is to the northeast at an angle of about 7°. The coal bed has a maximum thickness of 8 feet, but throughout much of its outcrop it is much thinner and in places is too thin and shaly to be of value. Where mined it has no partings. It is exposed at intervals for about 4 miles, mostly on the south side of the Popo Agie along slopes above a sandstone escarpment facing to the west.

Very thin layers of coal occur in the upper sandstone of the Colorado formation near Dallas post-office, 10 miles southeast of Lander, and have been prospected to some extent. They are mostly less than 2 inches in thickness and a few rods in horizontal extent, but at one point one of them attains a thickness of 18 inches. At this point an incline is driven 80 feet along the slope, and while the coal is of good quality the quantity is insufficient.

The principal openings from which coal has been mined in the Lander field are as follows:

Big mine.....NW. ¼ SW. ¼ sec. 3, T. 33 N., R. 98 W.
Little mine.....SW. ¼ SE. ¼ sec. 33, T. 34 N., R. 98 W.
Hayne's mine ...NW. ¼ SW. ¼ sec. 33, T. 34 N., R. 98 W.
Small drifts.....W. ½ SW. ¼ and SW. ¼ NW. ¼ sec. 28, T. 34 N., R. 98 W.
Small pit.....W. ½ NW. ¼ sec. 11, T. 34 N., R. 98 W.
Small slope.....E. ½ SW. ¼ SW. ¼ sec. 11, T. 34 N., R. 98 W.

The coal was first opened in 1885 and has been worked at intervals since. The total production in 1905 is estimated at 4,000 short tons. The Lander Coal Company is the chief producer. At the Big mine of this company there is a slope of 500 feet and a working face 8 feet thick. The mine is worked entirely by hand, except that tram cars are brought to the surface by a cable operated by horsepower windlass at the mouth of the mine. The room-and-pillar method of mining is used, and the roof is a sandy shale, which requires but little timbering. There is no water and no gas of any consequence. At the Little mine, three-fourths of a mile away, the conditions are similar, but the bed is only 4 feet thick. There is a 500-foot incline, with numerous rooms. In places in this mine the dip increases locally to 16°. Three miles southeast of the Little mine the coal appears to be represented by a number of thin beds with sandstone partings.

Hayne's mine is a small one, which has produced coal for a number of years. The small opening on the Indian reservation is operated under a lease from the Indians. The coal slacks and rapidly crumbles on exposure to weather, so that it is mined and marketed to meet only the immediate demand and mainly during the winter months. The market is Lander and vicinity, and the price at the mine $2.50 a short ton. During the past summer a branch of the Chicago and Northwestern Railway has been extended across this field to Lander, and probably in future some of the coal may be shipped over this line to more distant points. The following analyses were made in the laboratory of the United States Geological Survey fuel-testing plant at St. Louis by F. M. Stanton. The samples were selected so as to represent the freshly mined coal.

Analyses of coal from R. 98 W., near Lander, Wyo.

		T. 33 N.	T. 34 N.
Laboratory No.		4354	4355
Analysis of sample as received:			
Prox.	Moisture	21.20	22.90
	Volatile matter	35.85	38.09
	Fixed carbon	38.33	35.81
	Ash	4.62	3.20
Ult.	Sulphur	.53	.47
	Hydrogen	6.08	.....
	Carbon	55.25	.....
	Nitrogen	1.15	.....
	Oxygen	32.37	.....
Calorific value determined:			
	Calories	5,357	.....
	British thermal units	9,643	.....

		T. 33 N.	T. 34 N.
Loss of moisture on air drying		6.20	6.30
Analysis of air-dried sample:			
Prox.	Moisture	15.99	17.72
	Volatile matter	38.22	40.65
	Fixed carbon	40.86	38.22
	Ash	4.93	3.41
Ult.	Sulphur	.56	.50
	Hydrogen	5.75	.....
	Carbon	58.90	.....
	Nitrogen	1.23	.....
	Oxygen	28.63	.....
Calorific values determined:			
	Calories	5,711	.....
	British thermal units	10,280	.....

COAL FIELDS OF EAST-CENTRAL CARBON COUNTY, WYO.

By A. C. Veatch.

INTRODUCTION.

This paper is a preliminary statement of results of surveys made during the summer of 1906 by the writer, with the assistance of Max W. Ball, Max A. Pishel, and Spencer R. Logan. Mr. Logan had charge of the collection of coal samples, and it was due to his energy that so large a number were forwarded to the fuel-testing plant at St. Louis. Messrs. Ball and Pishel assisted in the topographic sketching and in the geologic mapping.

The method of work was in general the same as that used in Uinta County in 1905.[a] The region is covered by the public land surveys, and economic considerations demanded that the work be based primarily on the land-office subdivisions, since in such a region the section and its subdivisions are the units of economic importance in everything except lode claims. All locations were made by pacing section lines or from land corners found by such pacing. Elevations were determined by aneroid-barometer readings checked by hand-level sights and based on railroad surveys and the precise lines of levels of the United States Coast and Geodetic Survey and the United States Geological Survey. The field sheets, on a scale of 2 inches to the mile, contour interval 100 feet, are now being compiled into a base map on the scale of 1 inch to the mile. This will be used in the preparation of the geologic and other maps of the final report. The sketch map (Pl. XIV) accompanying this preliminary report has been hastily prepared from the field sheets, and though approximately correct may be found to disagree in minor particulars with the final large-scale map. The detailed report will probably be ready for distribution in the summer of 1908, and the reader is referred to it for an elaboration and amplification of the points here outlined and of the map here presented.

[a] Bull. U. S. Geol. Survey No. 285, 1906, p. 331; Prof. Paper U. S. Geol. Survey No. 56, 1907, pp. 1-3.

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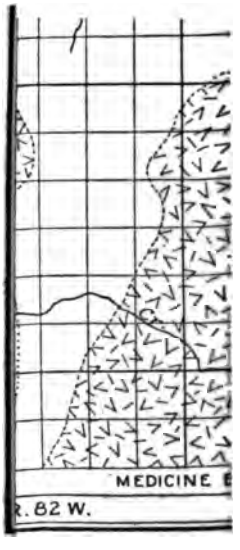

, WYO.

TOPOGRAPHY.

The area under consideration is situated on the western edge of the Rocky Mountains, just east of the great Green River Basin, and includes the western part of what is sometimes called the Laramie Plains. With reference to the general mountain uplift, the district is situated at the point where the collection of ranges known as the Rocky Mountains turn from the north-south course characteristic in Colorado and swing westward across Wyoming to the Yellowstone National Park. At this point of change of direction the mountains are broken into a number of dome and lozenge shaped uplifts of greater or less extent and of considerable variation in axial trend, and the coal area is thus a topographic and geologic basin with an average altitude between 6,500 and 7,000 feet, almost completely rimmed by uplifts ranging in elevation from 7,500 to over 11,000 feet. On the south it is limited by the abrupt north ends of the north-south Sierra Madre, or Park Range, and the Medicine Bow Mountains, and on the north by the east-west Freezeout, Bennett, Seminoe, and Ferris ranges. On the west the Rawlins Hills, an elongate dome with a granite core, together with the northern extension of the Sierra Madre, all but separate the coal basin from the eastern edge of the great Green River coal field. On the northeast and east are a few low domes, without much topographic importance, and to the southeast the area merges into the plains region, to which the name Laramie Plains is now usually restricted.

Within the basin area the principal topographic expression is due to the hard, resistant sandstones of the Mesaverde, which make notable ranges of hills, usually separated from the more elevated areas of older rocks by belts of low relief underlain by the soft shale of the lower Pierre. A group of these Mesaverde ridges, the Table, Haystack, and Rattlesnake hills, and Mead Ridge topographically connect the north end of the Medicine Bow Mountains with the Seminoe Mountains and were thus, in the early history of the country, naturally taken as the western limit of the Laramie Plains.[1]

GEOLOGY.

OUTLINE OF GEOLOGIC SUCCESSION.

The general character and succession of the Cretaceous and Tertiary rocks in this area, together with their economic importance, are shown in the accompanying table.

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[1] [illegible] Western Territories, sheet 1, scale 1:[illegible], 1876. Also earlier maps of the War Department.

Generalized section of Cretaceous and Tertiary rocks of central Carbon County, Wyo.

System.	Group.	Formation.	Thickness. (feet.)	Characteristics.	Economic value.
Tertiary.		North Park.	4,500	White volcanic-ash beds, cherty bands; base conglomeratic.	May yield artesian water.
		Unconformity.			
		Fort Union.	±1,200	Dark-colored shales and shaly sandstones.	
	Laramie (hitherto so called).	"Upper Laramie."	±6,800	Dark-colored shales and gray to brown, irregularly bedded sandstones; coal bearing. Contains conglomerate at base composed largely of pebbles derived from the underlying Cretaceous rocks. Fresh-water fauna.	**Prolifically coal bearing** throughout. Contains coal worked at the Carbon, Dana, and Hanna mines.
		Unconformity.			
		"Lower Laramie."	6,500	Dark-colored shales and gray to brown, irregularly bedded sandstones; coal bearing. Fresh-water fauna.	**Coal bearing.** Beds thinner and not so numerous as in overlying formations. Local mines at several points.
Cretaceous.	Montana.	Lewis.	1,800–3,000	Shales and shaly sandstones. Coal bearing. Has in parts of field a very persistent white sandstone near top. Marine and brackish-water faunas.	**Coal bearing.** Numerous important beds in region of Seminoe Mountains and O'Brien Spring. No development work of importance at other points.
		Mesaverde.	1,500–3,200	White to yellow sandstones and interbedded shales, coal bearing, producing areas of marked relief. Heaviest sandstones are grouped near top and at base of formation, and thus produce, under favorable conditions, two terraces or hogbacks.	**Coal bearing** above basal group of sandstones. Coal beds thin and rather irregular, but coal of high grade. Principal mines on Platte River 13 miles south of Fort Fred Steele. Basal sandstones quarried for building and sold commercially as "Rawlins sandstone."
		Pierre shale.[a]	3,000–3,500	Dark-gray to brown, sandy, concretionary shale and thin, soft shaly sandstones, producing areas of low relief.	
	Colorado.	Niobrara.	750–850	Dark-colored, very calcareous shale, weathering light gray.	
		Benton. Frontier.	150	Black shale.	
			400–800	Brown sandstones and shales, producing marked ridges.	
		Mowry.	300–750	Black fish-scale shale, weathering silver-gray.	
			10–15	Yellow quartzitic sandstone, resembling the Dakota.	
			60–150	Black shale, with thin coal beds.	
		Dakota.	80–125	Coarse conglomeratic sandstones.	Important artesian-water horizon.

[a] It is the belief of Dr. T. W. Stanton that the Mesaverde and part of the Lewis also belong to the Pierre, as that formation is developed east of the Rocky Mountains. A local name will therefore probably be applied to this lowest division of the Montana in this region.

COAL-BEARING FORMATIONS.

LOWER COLORADO.

The oldest beds containing coal in this area are in the lower part of the Cretaceous as here developed. At this horizon black shale, occurring between typical Dakota sandstone and the Mowry fish-scale shale and tentatively referred to the Colorado, contains beds of dirty coal a few inches thick. The occurrence is of scientific interest only, and suggests the coal in the Bear River formation of Uinta County, Wyo., and the Lakota coals of the Black Hills region, though apparently higher than the latter. The overlying Frontier formation, which is the important coal-bearing formation in Uinta County, is apparently barren here.

MESAVERDE FORMATION.

The first important coal-bearing formation in this section is the Mesaverde, of lower Montana (Cretaceous) age. The basal 500 to 1,500 feet of this formation consist of heavy ridge-making sandstones, which, so far as known, are not coal bearing. Coal beds occur irregularly throughout the remainder of the formation. The individual beds are irregular and not persistent. The coal is, however, of high grade, and at the Larson mine a bed 16 inches thick has been worked and the product hauled to Saratoga. In T. 19 N., Rs. 85–86 W., there has been considerable prospecting done on the Kindt coal bed and several mines opened which exhibit the following sections:

Sections of coal beds in Mesaverde formation.

Location.			Section.		
T.	R.	Sec.		*Ft.*	*in.*
19	86	14, SW. ¼ SE. ¼.	Coal	1	6
			Shale		9
			Bone		6
			Coal	1	1
				3	10
19	86	14, SE. ¼ SE. ¼.	Coal	6	
19	85	19, SW. ¼ NW. ¼.	Coal	2	2
			Shale		9
			Coal	1	6
				4	5
19	85	19, SE. ¼ NW. ¼.	Coal	5	3
19	85	19, NE. ¼ SE. ¼.	Coal		7
			Shale		8
			Coal	4	8
				5	11

Location.			Section.		
T.	R.	Sec.		*Ft.*	*in.*
19	85	19, NE. ¼ SE. ¼.	Coal	2	
			Shale		10
			Coal	1	
				3	10
19	85	20, NW. ¼ SW. ¼.	Coal	1	10
			Shale	1	6
			Coal	1	4
				4	8
19	85	20, NW. ¼ SE. ¼.	Coal	2	
			Shale	4	6
			Coal	1	
				7	6

Mines have been opened in secs. 22 and 36, T. 21 N., R. 88 W., in beds just below the upper escarpment and 500 feet or more above the beds worked at the Larson and Petty mines. Workable beds have been found in the same horizon in sec. 13, T. 20 N., R. 87 W., and sec. 19, T. 20 N., R. 86 W. At O'Brien Spring, in sec. 9, T. 24 N., R. 85 W., coal is found in the upper group of sandstones. At the Fieldhouse opening, in sec. 23, T. 25 N., R. 86 W., and on upper Medicine Bow River, in sec. 34, T. 21 N., R. 79 W., coal is found immediately overlying the upper sandstones in the uppermost part of the Mesaverde or basal portion of the Lewis. The character and thickness of the coal beds in the middle and upper parts of the coal-bearing portion of the Mesaverde are shown in the following sections:

Sections of coal beds in Mesaverde formation.

Location.			Section.			Location.			Section.		
T.	R.	Sec.		Ft.	in.	T.	R.	Sec.		Ft.	in.
21	88	22, SW. ¼ SE. ¼.	Coal	3	0	25	86	23, SE. ¼ NE. ¼ (Fieldhouse mine).	Coal		8
			Sandstone		2				Shale		1
			Coal	3					Coal	3	6
			Coal, dirty		2				Coal, dirty	3	8
			Coal	1	6					7	11
				7	10						
21	88	36, NE. ¼ NW. ¼ (Dillon mine).	Coal	2	10	24	85	9, NE. ¼ SW. ¼ (O'Brien Spring mine).	Coal, dirty		5
			Coal, dirty		2				Sandstone		8
			Coal	1	6				Coal	1	2
				4	6				Bone		7
									Coal		8
									Coal, dirty		8
20	87	Line between NE. ¼ NE. ¼ sec. 24 and SE. ¼ SE. ¼ sec. 13.	Coal	4	6				Coal		10
										5	
20	86	19, NW. ¼ NW. ¼.	Coal		7	21	79	34, SE. ¼ NW. ¼.	Shale, black.		
			Coal, dirty		½				Coal	1	6
			Coal		7				Dirt		½
			Coal, dirty		9				Coal	2	...
			Coal	2	3				Dirt		¾
				4	2½				Coal	1	...
									Shale, black	4	7½

LEWIS FORMATION.

The Lewis formation, which overlies the Mesaverde, is distinguished from that formation on lithologic grounds only. The Mesaverde contains many sandstones which produce a hilly region, but the Lewis is composed of shale and soft shaly sandstone which produce a region of low relief, contrasting markedly with the hilly area of the Mesaverde. This formation has been found prolifically coal bearing in the region south of Knapp and west of O'Brien Spring, where the following sections were measured.

Sections of coal beds in Lewis formation.

Location. T.	R.	Sec.	Section.	Ft.	in.
24	86	26, NE. ¼ NW. ¼.	Coal, with less of fire clay near center		10
24	86	26, SE. ¼ NW. ¼.	Coal	2	10
			Shale		1
			Coal	2	6
				5	5
25	85	20, NW. ¼ NW. ¼.	Coal	3	6
			Shale		1
			Coal	1	3
				4	10

Location. T.	R.	Sec.	Section.	Ft.	in.
25	85	20, NE. ¼ NW. ¼ (Penn. Wyoming mine).	Coal	4	10
25	85	17, NW. ¼ SW. ¼ (outer, Kronkheit mine).	Coal	8	6
25	85	17, NW. ¼ SW. ¼ (inner, Kronkheit mine).	Coal	5	
25	85	35, NE. ¼ SW. ¼ (Miller mine).	Coal	4	
			Coal, bony	1	
			Coal	6	6
				11	6

At Knapp the beds are overthrust by the iron-bearing metamorphic pre-Cambrian rocks, and the Seminoe hematite deposits are thus underlain by coal. The beds here occur in a syncline, the north limb of which is overturned and dips at angles of 110° to 150° NE. The south limb is comparatively flat, dipping from 10° to 15° (Pl. XIV).

"LOWER LARAMIE."

The "Lower Laramie" beds are similar to the Lewis beds in every way, and like them are coal bearing. Their separation from the Lewis is of scientific interest only, and is based on the absence of marine fossils in the "Lower Laramie" and their presence in the Lewis. Coal has been found in this formation at many points, as shown by the following sections, but has not been extensively developed because of the overshadowing importance of the coal in the "Upper Laramie."

Sections of coal beds in "Lower Laramie" formation.

Location. T.	R.	Sec.	Section.	Ft.	in.
24	83	11, SW. ¼ NE. ¼.	Coal	4	3
			Shale		½
			Coal	1	2
				5	5½
24	83	7, NW. ¼ NW. ¼.	Coal	4	4
			Shale	1	6
			Sandstone	1	2
			Coal	4	8
				11	8
20	83	1, NW. ¼ SE. ¼.	Coal, dirty	1	9
			Coal	7	3
				9	

Location. T.	R.	Sec.	Section.	Ft.	in.
21	84	14, SE. ¼ SW. ¼ (Buckley & Ryan mine).	Coal, dirty		8
			Coal	4	
				4	8
21	84	24, NE. ¼ SE. ¼.	Coal, bony	1	3
			Coal	3	9
				5	
22	85	2, NE. ¼ NW. ¼.	Coal	3	8

"UPPER LARAMIE."

The "Upper Laramie" is separated from the "Lower Laramie" by a great unconformity, which marks one of the important episodes in the geologic history of this region. This formation is prolifically coal bearing, some of the coal beds reaching a thickness of more than 30 feet. The following sections illustrate the thickness of the "Upper Laramie" coal beds:

Sections of coal beds in "Upper Laramie" formation.

Location.			Section.		
T.	R.	Sec.		Ft.	in.
22	81	16 (Hanna mine No. 1).	Coal	6	7
			Coal, bony	1	2
			Coal	8	
			Coal, bony	1	4
			Coal	5	
				22	1
22	82	32, SE. ¼.	Coal	5	
			Shale		¼
			Coal	7	7
				12	7¼
24	81	33, NE. ¼ SE. ¼ (Rock Crossing mine).	Coal, dirty	2	6
			Shale		2
			Coal		7
			Coal, dirty		6
			Shale		2
			Coal		6
				4	5
22	80	36, SE. ¼ SE. ¼ (mine No. 7, Carbon).	Coal	3	
			Shale		1
			Coal	2	2
			Coal, dirty		6
			Coal	2	
				7	9

Location.			Section.		
T.	R.	Sec.		Ft.	in.
21	80	28, SW. ¼ NW. ¼.	Coal	4	
			Shale		2
			Coal	7	
				11	2
21	80	32, SE. ¼ NE. ¼ (Finch mine).	Coal, dirty	4	
			Coal, fair	4	6
			Coal, good	2	6
				11	
22	81	18, SE. ¼ (bed worked at Hanna mine No. 2).	Coal, soft, dirty.	5	
			Coal, good	1	9
			Bone		7
			Coal, clean, hard.	19	6
			Bone		6
			Coal, clean, hard.	7	
			Coal and shale.	4	6
				38	10

STRUCTURE OF THE COAL FIELDS.

The coal-bearing rocks in this area occur in two basins, the second of which is separated into several subordinate basins. The first, called the Kindt Basin, is really but a projecting portion of the great Green River Basin lying to the west, from which it is all but separated by the northward-plunging anticline of the Sierra Madre uplift and the Rawlins uplift. This basin has very steep dips, 45° to 75°, on the north side, and much lower dips on the south. It is somewhat broken by minor folds, such as that producing the marked reentrant in the southern border of the Mesaverde formation in T. 19 N., R. 87 W. (Pl. XIV, p. 244). The eastern edge of the basin is buried beneath Tertiary deposits, but there are many reasons for believing that the coal-bearing beds are entirely separated from those in the basin to the east.

The second of the two larger coal basins of this area includes the

region rimmed in on the west by the Table, Haystack, and Rattlesnake hills. It is separated by the Simpson Ridge anticline into two major parts, the western of which is called the Hanna Basin and the eastern the Carbon Basin. The Hanna Basin is in a general way a broad trough 40 miles long and 25 miles wide, which shows minor folds and faults in the center and near its edges some marked irregular plunging anticlines, such as (1) the St. Mary anticline, extending northward from Elk Mountain to the Haystacks, just inside of and parallel to the southwest side of the basin, and separating the Walcott basin of "Lower Laramie" coals from the main field; (2) the O'Brien Spring anticline, which produces the semi-isolation of the Seminoe field, and (3) the Simpson Ridge anticline, which separates nearly all of this basin from the Carbon Basin.

The Carbon Basin is more irregular than the Hanna Basin. Its southern limit was not determined by the work of this party, but has been shown by the work of parties under N. H. Darton to lie just north of Rock Creek. This basin is very irregular in outline and is broken near its center by a slightly elongate dome, which brings up the Mesaverde strata.

QUALITY OF COALS.

METHOD OF TAKING SAMPLES.

Representative samples of coals were collected throughout the field and were sent in air-tight cans to the fuel-testing plant at St. Louis, where they were analyzed under the direction of F. M. Stanton.

In order that the results from the samples collected by many persons might be entirely comparable, all sampling was done in accordance with the general plan adopted by the fuel-testing plant and described by M. R. Campbell in a letter of instructions, as follows:

All mine samples should be obtained by cutting a channel across a clean face of the coal bed, or across such bench or benches as it is desirable to test, including everything except partings and binders over one-fourth inch in thickness and lenses and concretions greater than 2 inches in diameter and one-half inch in thickness. The channels should be of such a size as to furnish about 5 pounds of coal per foot of bed, and the material thus obtained should be caught upon a blanket of canvas or oilcloth to keep out dirt and excess moisture.

In order to preserve the original moisture content unchanged the gross sample should be pulverized in the mine as rapidly as possible until none of the fragments exceed one-half inch in diameter. The fine coal should then be mixed thoroughly and divided into four equal quarters. Opposite quarters should be thrown out and the remaining portions thoroughly mixed and again quartered, throwing out opposite quarters as before. This process should be continued until the sample is reduced to about 1 quart. The sample should then be placed in a can, and the latter sealed air-tight before leaving the mine. The geologist or sampler should always go provided with a small roll of adhesive tape for this purpose, so that there can be no excuse for leaving the sample unsealed.

METHOD OF MAKING ANALYSES.

It is evident that beyond the moisture natural or inherent to a coal, if this indeed be a definite quantity, samples from a wet mine hermetically sealed in the mine will contain a great deal more moisture than the same coal from a dry mine. In order that the coals may be readily compared it is necessary to reduce the different samples to something approaching the same moisture content. In the early work of the fuel-testing plant this was done by exposing the pulverized sample to the air of the laboratory for twenty-four hours, or until its weight became relatively uniform, and the loss on drying was called the "air-drying loss." This method proved unsatisfactory because of the varying humidity of the room and a new method was adopted, which has been briefly described by N. W. Lord as follows:[a]

> In order to make determinations of the loosely held moisture more uniform and definite, a special drying oven has been designed and introduced into the laboratory; in this oven samples of several pounds weight can be dried in a gentle current of air raised from 10° to 20° above the temperature of the laboratory. In this way the coal is air dried in an atmosphere with a very low dew-point and not subject to large percentage variations, and the results obtained are considerably more concordant. Another advantage of this method is that it greatly shortens the time of air drying, so that the samples can be prepared in much less time than formerly.

In other respects the chemical analyses here reported were made in the same general way as those described in the first report of the fuel-testing plant.[b]

ANALYSES.

The analytical results are presented below in two sets—one giving the result of analysis of samples as received in the laboratory, containing all the moisture; the second, which is calculated from the first, giving the result expressed in terms of the air-dried sample, that is, one lacking the moisture which in that particular sample, under the conditions of the analysis, was lost in air drying. The analyses are grouped according to the geologic age of the beds sampled.

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[a] Bull. U. S. Geol. Survey No. 290, 1906, pp. 29, 30.

[b] Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, pp. 174–192.

Analyses of coal from east-central Carbon County, Wyo.

SAMPLES AS RECEIVED.

No.	Geologic horizon of coal.		Thickness of coal represented by sample.		Locality.	Laboratory No.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Proximate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Loss of moisture on air drying.	Calorific value. Calories.	Calorific value. B. T. U.
			Ft.	*in.*														
1	Mesaverde.	Lower.	5	2	Fort Steele, 13 miles south of, SW. ¼ SW. ¼ sec. 19, T. 19 N., R. 85 W	3480	8.85	36.58	50.99	3.58	0.92	5.76	68.68	1.73	19.33	3.60	6,701	12,062
2			4	6	Fort Steele, 13 miles south of, SW. ¼ NW. ¼ sec. 19, T. 19 N., R. 85 W	3481	9.87	36.27	51.88	1.98	.90					4.10		
3			2	6	Fort Steele, 13 miles south of, NW. ¼ SW. ¼ sec. 26, T. 19 N., R. 85 W	3509	7.51	37.80	48.81	5.88	.86	5.28	67.62	1.76	18.60	1.90	6,631	11,936
4			1	4	Fort Steele, 13 miles south of, NE. ¼ NE. ¼ sec. 28, T. 19 N., R. 85 W	3501	7.55	40.13	49.59	2.73	.74					1.80		
5			2	8	Fort Steele, 14 miles south of, SW. ¼ NE. ¼ sec. 35, T. 19 N., R. 85 W	3507	6.87	43.51	45.15	4.47	.89					.80		
6		Middle.	1	4	Fort Steele, 14 miles south of, NW. ¼ SW. ¼ sec. 36, T. 19 N., R. 85 W	3508	20.19	33.48	38.92	7.41	.70					7.70		
7			4	6	Rawlins, 4 miles southwest of, NE. ¼ NW. ¼ sec. 36, T. 21 N., R. 88 W	3477	13.23	33.57	46.37	6.83	.63					6.70		
8			4	6	Same	3478	14.12	32.95	46.37	6.56	.49					7.30		
9			4	6	Rawlins, 8 miles southeast of, NE. ¼ NW. ¼ sec. 24, T. 20 N., R. 87 W.; surface sample	3479	28.09	27.04	34.55	10.32	.29					21.20		
10			3	4	Fort Steele 20 miles north of, NE. ¼ SW. ¼ sec. 9, T. 24 N., R. 85 W	3921	13.54	32.01	48.34	6.11	.50					7.00		
11		Upper.	4	1	Fort Steele, 13 miles northwest of, SE. ¼ NE. ¼ sec. 18, T. 23 N., R. 85 W.; surface sample	3931	19.26	31.79	44.62	4.33	.53					11.00		
12			4	2	Fort Steele, 25 miles northwest of, SE. ¼ NE. ¼ sec. 23, T. 25 N., R. 86 W.; upper part of bed 7 feet 10 inches thick	3925	14.04	33.79	45.58	6.59	.40					5.20		
13			4	6	Carbon, 9 miles southeast of, SE. ¼ NW. ¼ sec. 34, T. 21 N., R. 79 W	3649	14.53	36.84	44.40	4.23	.53					5.30		
14	Lewis.		4		Fort Steele, 18 miles northwest of, NE. ¼ NW. ¼ sec. 26, T. 24 N., R. 86 W.; upper part of 10-foot bed	3928	19.19	28.39	43.59	8.83	.48					11.90		
15			5		Same: lower part of 10-foot bed	3926	32.63	25.93	30.52	10.92	.28					23.30		
16			5	8	Fort Steele, 18 miles northwest of, SW. ¼ SE. ¼ sec. 23, T. 24 N., R. 86 W.; upper part of 10-foot bed	3930	31.72	29.75	34.94	3.59	.44					21.90		
17			10	6	Fort Steele, 22 miles north of, NE. ¼ SW. ¼ sec. 35, T. 25 N., R. 85 W.; upper bed	3917	15.46	36.16	44.86	3.52	.79	5.60	58.87	1.44	29.78	7.40	5,843	10,517
18			6	6	Same: lower part of upper bed	3918	14.52	36.13	46.57	2.78	.45					6.70		
19			2	6	Same: lower bed	3915	13.97	34.13	48.57	3.33	.47					5.80		
20			8		Fort Steele, 25 miles northwest of, NW. ¼ SW. ¼ sec. 17, T. 25 N., R. 85 W.; lower bed	3922	13.90	36.16	45.75	4.19	.36	5.45	59.98	1.35	28.67	5.70	5,846	10,523

Analyses of coal from east-central Carbon County, Wyo.—Continued.

SAMPLES AS RECEIVED.

No.	Geologic horizon of coal.	Thickness of coal represented by sample.		Locality.	Laboratory No.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Ultimate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Loss of moisture on air drying.	Calorific value. Calories.	Calorific value. B. T. U.
		Ft.	*in.*														
21	Lewis.	8	6	Same; upper bed	3920	12.31	36.06	46.47	5.16	0.33	5.54	61.65	1.34	25.98	4.60	5,925	10,665
22		5	3	Fort Steele, 24 miles northwest of, SW. ¼ NE. ¼ sec. 20, T. 25 N., R. 85 W	3916	33.81	30.45	32.37	3.37	.15					24.30		
23		4	9	Fort Steele, 24 miles northwest of, SE. ¼ SE. ¼ sec. 20, T. 25 N., R. 85 W	3923	33.64	31.90	30.59	3.87	.27					24.20		
24		4	10	Fort Steele, 24 miles northwest of, SW. ¼ SE. ¼ sec. 20, T. 25 N., R. 85 W	3919	18.41	34.50	43.38	3.71	.28	5.52	53.87	1.29	35.33	10.00	5,072	9.131
25	"Lower Laramie."	4	4	Hanna, 19 miles northwest of, NW. ¼ NW. ¼ sec. 7, T. 24 N., R. 83 W.; separated from No. 26 by 2 feet 10 inches of shale and sandstone; surface sample	3824	39.07	29.31	27.94	3.68	.63					30.50		
26		4	8	Same	3807	39.40	27.67	29.39	3.54	.30					30.00		
27		5	6	Hanna, 16 miles northwest of, SW. ¼ NE. ¼ sec. 11, T. 24 N., R. 83 W	3790	13.06	35.11	48.86	2.97	1.10	5.52	61.72	1.38	27.31	3.70	6,041	10,874
28		4		Walcott, 25 miles north of, SE. ¼ SW. ¼ sec. 14, T. 21 N., R. 84 W	3538	12.08	35.40	49.68	2.84	.47					3.10		
29		4		Same; but at different point in mine	3544	11.17	35.42	50.57	2.84	.50					2.50		
30		7	3	Walcott, 9 miles southeast of, NW. ¼ SE. ¼ sec. 1, T. 20 N., R. 83 W	3548	10.96	38.04	48.59	2.41	.29	5.37	62.25	1.59	28.09	.80	5,902	10,624
31		3	8	Fort Steele, 8 miles north of, NE. ¼ NW. ¼ sec. 2, T. 22 N., R. 85 W.; surface sample	3929	20.41	37.64	37.31	4.64	.25					9.10		
32		8	6	Carbon, 6 miles southeast of, SE. ¼ SE. ¼ sec. 20, T. 21 N., R. 79 W	3547	18.71	36.38	38.46	6.45	.47					8.10		
33		4	10	Carbon, 9 miles southwest of, lot No. 2, sec. 6, T. 20 N., R. 80 W.; upper part of a 14½-foot bed	3651	30.13	31.38	35.52	2.97	.33					16.70		
34		5		Same; lower 5 feet of same bed	3650	14.66	35.71	44.41	5.22	.38					6.20		
35		4		Carbon, 6½ miles southwest of, SW. ¼ NW. ¼ sec. 28, T. 20 N., R. 80 W.; upper part of 12-foot seam	3648	6.79	45.80	41.10	6.31	.63					1.40		
36		6		Same; lower part of same bed	3645	9.21	41.56	44.86	4.37	.67					2.90		
37		7		Carbon, 7½ miles south of, lot No. 3, sec. 4, T. 20 N., R. 80 W.; lower part of 14½-foot bed	3644	13.28	37.54	42.53	6.65	.48					5.00		
38		7		Carbon, SW. ¼ SE. ¼ sec. 26, T. 22 N., R. 80 W.; coal weathered	3735	9.20	41.10	44.16	5.54	1.01					3.10		
39		4		Same; 150 feet from mouth of slope, lower part of 7-foot bed	3739	8.31	39.85	42.34	9.50	.92					3.00		
40		7		Same; 225 feet from mouth of slope	3664	8.77	39.74	45.52	5.97	1.00					1.10		

41	"Upper Laramie."	4	9	Carbon, ¼ mile west of, NE. ¼ SE. ¼ sec. 27, T. 22 N., R. 80 W	3740	11.92	36.37	46.18	5.53	1.71					4.10		
42		4	9	Same	3741	13.24	35.71	43.59	7.46	1.39					5.20		
43		7	2	Carbon, SW. ¼ SE. ¼ sec. 36, T. 22 N., R. 80 W.	3743	10.23	38.14	42.45	9.18	1.16					3.80		
44		8		Same	3742	11.55	33.78	44.41	10.26	1.23					4.90		
45		7	6	Walcott, 12 miles north of, NW. ¼ SW. ¼ sec. 25, T. 23 N., R. 84 W	3808	13.59	31.77	49.35	5.29	.33	5.22	61.06	.83	27.28	4.30	5,785	10,413
46		7		Walcott, 12 miles north of, SE. ¼ SW. ¼ sec. 25, T. 23 N., R. 84 W	3826	13.19	31.70	50.23	4.88	.24					2.30		
47		7		Same; surface sample	3806	24.54	32.45	37.38	5.63	.24					5.10		
48		10		Walcott, 11 miles north of, SW. ¼ SW. ¼ sec. 36, T. 23 N., R. 84 W.; upper part of bed of undetermined thickness; surface sample	3927	29.96	29.55	36.93	3.56	.16					21.00		
49		5		Walcott, 11 miles north of, NW. ¼ NE. ¼ sec. 2, T. 22 N., R. 84 W.; upper part of bed of undetermined thickness; surface sample	3924	27.39	32.52	33.31	6.78	.35					18.70		
50		4		Hanna, 11 miles northeast of, sec. 35, T. 24 N., R. 81 W	3780	15.33	33.63	45.34	5.70	2.27	6.04	57.02	1.63	27.34	5.80	5,690	10,242
51		4		Hanna, 11 miles northeast of, NE. ¼ SE. ¼ sec. 33, T. 24 N., R. 81 W	3781	12.33	35.05	46.21	6.41	2.78					4.40		
52		4		Same	3779	12.89	34.34	44.07	8.70	2.97					4.40		
53		5		Hanna, 4 miles north of, NW. ¼ NW. ¼ sec. 31, T. 23 N., R. 81 W.; surface sample	3822	16.93	32.38	48.08	2.61	.53					7.90		
54		6		Como, 2 miles west of, SW. ¼ NW. ¼ sec. 32, T. 23 N., R. 80 W	3736	24.58	31.43	41.93	2.06	.88					11.80		
55		6		Como, 2 miles west of, SE. ¼ NW. ¼ sec. 32, T. 23 N., R. 80 W.; upper part of 12-foot bed; surface sample	3738	18.43	35.09	42.90	3.58	.83					9.20		
56		6		Same; lower part of 12-foot bed; surface sample	3737	20.33	32.29	44.63	2.75	.62					8.80		
57		3	6	Hanna, 1 mile southwest of, SE. ¼ NW. ¼ sec. 24, T. 22 N., R. 82 W.; part of bed just below Hanna No. 2	3616	13.12	41.42	39.78	5.68	.45					3.30		
58		8		Hanna, lower bench of No. 2 seam	3610	11.45	42.58	39.33	6.64	.38	5.27	59.66	.94	27.11	2.50	6,050	10,890
59		8		Hanna, upper part of middle bench of No. 2 seam	3611	12.34	40.71	42.42	4.53	.23					2.60		
60		7		Hanna, prospect on No. 2 seam; sample represents middle bench	3617	13.04	40.60	41.80	4.56	.22					3.40		
61		5		Hanna, prospect on seam between Nos. 1 and 2, SW. ¼ sec. 17, T. 22 N., R. 81 W	3615	11.89	43.21	38.80	6.10	.56					2.60		
62		5	3	Hanna, middle bench of No. 1 seam, 19 to 25 feet thick	3612	11.21	42.59	42.03	4.17	.33					2.10		
63		6	2	Same; middle bench of No. 1 seam	3613	11.82	41.78	42.11	4.29	.29					3.10		
64		7	3	Same; middle bench of No. 1 seam	3614	12.29	42.11	41.11	4.49	.33					3.30		
65		5		Hanna, lower part of top bench of No. 1 seam	3605	10.09	41.01	41.91	6.99	.49	5.53	62.66	1.26	23.07	2.20	6,279	11,302
66		9	4	Same; middle bench of No. 1 seam	3606	9.57	42.69	40.44	7.30	.39	5.50	62.82	1.31	22.68	1.40	6,249	11,248
67		4		Same; bottom bench of No. 1 seam	3607	11.80	41.66	40.25	6.29	.44	5.79	62.45	.99	24.04	2.20	6,150	11,070
68		5		Same; upper part of middle bench of No. 1 seam	3608	9.81	43.39	40.68	6.12	.51					1.90		
69		8		Same; middle bench of No. 1 seam	3609	10.65	40.79	41.41	7.15	.39					2.20		

Analyses of coal from east-central Carbon County, Wyo.—Continued.

AIR-DRIED SAMPLES.

No.	Geologic horizon of coal.		Thickness of coal represented by sample.		Locality.	Laboratory No.	Proximate.				Ultimate.					Percentage of water to be added to convert to sample as received.	Calorific value.	
							Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	B. T. U.
			Ft.	*in.*														
1	Mesaverde.	Lower.	5	2	Fort Steele, 13 miles south of, SW. ¼ SW. ¼ sec. 19, T. 19 N., R. 85 W	3480	5.45	37.95	52.89	3.71	0.95	5.56	71.24	1.79	16.73	3.73	6,951	12,512
2			4	6	Fort Steele, 13 miles south of, SW. ¼ NW. ¼ sec. 19, T. 19 N., R. 85 W	3481	6.02	37.82	54.10	2.06	.94					4.28		
3			2	6	Fort Steele, 13 miles south of, NW. ¼ SW. ¼ sec. 26, T. 19, R. 85 W	3509	5.72	38.53	49.76	5.99	.88	5.17	68.93	1.79	17.24	1.94	6,759	12,167
4			1	4	Fort Steele, 13 miles south of, NE. ¼ NE. ¼ sec. 28, T. 19 N., R. 85 W	3501	5.86	40.87	50.50	2.78	.75					1.83		
5			2	8	Fort Steele, 14 miles south of, SW. ¼ NE. ¼ sec. 35, T. 19 N., R. 85 W	3507	6.12	43.86	45.51	4.51	.90					.81		
6			1	4	Fort Steele, 14 miles south of, NW. ¼ SW. ¼ sec. 36, T. 19 N., R. 85 W	3508	13.53	36.27	42.17	8.03	.76					8.34		
7		Middle.	4	6	Rawlins, 4 miles southwest of, NE. ¼ NW. ¼ sec. 36, T. 21 N., R. 88 W	3477	7.00	35.98	49.69	7.32	.67					7.18		
8			4	6	Same	3478	7.36	35.54	50.02	7.08	.53					7.87		
9			4	6	Rawlins, 8 miles southeast of, NE. ¼ NW. ¼ sec. 24, T. 20 N., R. 87 W.; surface sample	3479	8.74	34.31	43.85	13.10	.37					26.90		
10		Upper.	3	4	Fort Steele, 20 miles north of, NE. ¼ SW. ¼ sec. 9, T. 24 N., R. 85 W	3921	7.03	34.42	51.98	6.57	.54					7.53		
11			4	1	Fort Steele, 13 miles northwest of, SE. ¼ NE. ¼ sec. 18, T. 23 N., R. 85 W.; surface sample	3931	9.28	35.72	50.13	4.87	.60					12.36		
12			4	2	Fort Steele, 25 miles northwest of, SE. ¼ NE. ¼ sec. 23, T. 25 N., R. 86 W.; upper part of a bed 7 feet 10 inches thick	3925	9.32	35.64	48.08	6.95	.42					5.49		
13			4	6	Carbon, 9 miles southeast of, SE. ¼ NW. ¼ sec. 34, T. 21 N., R. 79 W	3649	9.75	38.90	46.88	4.47	.56					5.60		
14	Lewis.		4		Fort Steele, 18 miles northwest of, NE. ¼ NW. ¼ sec. 26, T. 24 N., R. 86 W.; upper part of 10-foot bed	3928	8.27	32.22	49.48	10.02	.54					13.51		
15			5		Same; lower part of 10-foot bed	3926	12.16	33.81	39.79	14.24	.37					30.38		
16			5	8	Fort Steele, 18 miles northwest of, SW. ¼ SE. ¼ sec. 23, T. 24 N., R. 86 W.; upper part of 10-foot bed	3930	12.57	38.09	44.74	4.60	.56					28.04		
17			10	6	Fort Steele, 22 miles north of, NE. ¼ SW. ¼ sec. 35, T. 25 N., R. 85 W.; upper bed	3917	8.70	39.05	48.44	3.80	.85	5.16	63.57	1.56	25.05	7.99	6,310	11,357
18			6	6	Same; lower part of upper bed	3918	8.38	38.72	49.91	2.98	.48					7.18		
19			2	6	Same; lower bed	3915	8.67	36.23	51.56	3.54	.50					6.16		
20			8		Fort Steele, 25 miles northwest of, NW. ¼ SW. ¼ sec. 17, T. 25 N., R. 85 W.; lower bed	3922	8.70	38.35	48.52	4.44	.38	5.11	63.61	1.43	25.03	6.04	6,199	11,159

21		8	6	Same; upper bed	3920	8.08	37.80	48.71	5.41	.35	5.27	64.62	1.39	22.95	4.82	6,211	11,179
22	Lewis.	5	3	Fort Steele, 24 miles northwest of, SW. ¼ NE. ¼ sec. 20, T. 25 N., R. 85 W	3916	12.56	40.22	42.76	4.45	.20					32.10		
23		4	9	Fort Steele, 24 miles northwest of, SE. ¼ SE. ¼ sec. 20, T. 25 N., R. 85 W	3923	12.45	42.08	40.36	5.11	.36					31.93		
24		4	10	Fort Steele, 24 miles northwest of, SW. ¼ SE. ¼ sec. 20, T. 25 N., R. 85 W	3919	9.34	38.33	48.20	4.12	.31	4.90	59.86	1.43	29.39	11.11	5,636	10,144
25	"Lower Laramie."	4	4	Hanna, 19 miles northwest of NW. ¼ NW. ¼ sec. 7, T. 24 N., R. 83 W.; separated from No. 26 by 2 feet 10 inches of shale and sandstone; surface sample	3824	12.33	42.17	40.20	5.29	.91					43.88		
26		4	8	Same	3807	13.43	39.53	41.98	5.06	.43					42.86		
27		5	6	Hanna, 16 miles northwest of, SW. ¼ NE. ¼ sec. 11, T. 24 N., R. 83 W	3790	9.72	36.46	50.74	3.08	1.14	5.31	64.09	1.43	24.95	3.84	6,273	11,292
28		4		Walcott, 2 miles north of, entry No. 4, SE. ¼ SW. ¼ sec. 14, T. 21 N., R. 84 W	3538	9.27	36.53	51.27	2.93	.49					3.20		
29		4		Same, but at different point in mine	3544	8.89	36.33	51.87	2.91	.51					2.56		
30		7	3	Walcott, 9 miles southeast of, NW. ¼ SE. ¼ sec. 1, T. 20 N., R. 83 W	3548	10.24	38.35	48.98	2.43	.29	5.32	62.75	1.60	27.60	.81	5,950	10,710
31		3	8	Fort Steele, 8 miles north of, NE. ¼ NW. ¼ sec. 2, T. 22 N., R. 85 W.; surface sample	3929	12.44	41.41	41.05	5.10	.28					10.01		
32	"Upper Laramie."	8	6	Carbon, 6 miles southeast of, SE. ¼ SE. ¼ sec. 20, T. 21 N., R. 79 W	3647	11.54	39.59	41.85	7.02	.51					8.81		
33		4	10	Carbon, 9 miles southwest of, lot No. 2, sec. 6, T. 20 N., R. 80 W.; upper part of a 14½-foot bed	3651	16.12	37.67	42.64	3.57	.40					20.05		
34		5		Same; lower 5 feet of same bed	3650	9.02	38.07	47.35	5.56	.40					6.61		
35		4		Carbon, 6½ miles southwest of, SW. ¼ NW. ¼ sec. 28, T. 20 N., R. 80 W.; upper part of 12-foot seam	3648	5.47	46.45	41.68	6.40	.64					1.42		
36		6		Same; lower part of same bed	3645	6.50	42.80	46.20	4.50	.69					2.99		
37		7		Carbon, 7½ miles south of, lot No. 3, sec. 4, T. 20 N., R. 80 W.; lower part of 14½-foot bed	3644	8.71	39.52	44.77	7.00	.51					5.26		
38		7		Carbon, SW. ¼ SE. ¼ sec. 26, T. 22 N., R. 80 W.; coal weathered	3735	6.29	42.41	45.57	5.72	1.04					3.20		
39		4		Same; 150 feet from mouth of slope; lower part of 7-foot bed	3739	5.47	41.08	43.65	9.79	.95					3.09		
40		7		Same; 225 feet from mouth of slope	3664	7.76	40.18	46.03	6.04	1.01					1.11		
41		4	9	Carbon, ½ mile west of, NE. ¼ SE. ¼ sec. 27, T. 22 N., R. 80 W	3740	8.15	37.92	48.15	5.77	1.78					4.28		
42		4	9	Same	3741	8.48	37.67	45.98	7.87	1.47					5.49		
43		7	2	Carbon, SW. ¼ SE. ¼ sec. 36, T. 22 N., R. 80 W.	3743	6.68	39.65	44.13	9.54	1.21					3.95		
44		8		Same	3742	6.99	35.52	46.70	10.79	1.29					5.15		
45		7	6	Walcott, 12 miles north of, NW. ¼ SW. ¼ sec. 25, T. 23 N., R. 84 W	3808	9.71	33.20	51.57	5.53	.34	4.95	63.80	.87	24.51	4.49	6,045	10,881
46		7		Walcott, 12 miles north of, SE. ¼ SW. ¼ sec. 25, T. 23 N., R. 84 W	3826	11.15	32.45	51.41	4.99	.25					2.35		
47		7		Same; surface sample	3806	20.48	34.19	39.39	5.93	.25					5.37		
48		10		Walcott, 11 miles north of, SW. ¼ SW. ¼ sec. 36, T. 23 N., R. 84 W.; upper part of bed of undetermined thickness; surface sample	3927	11.34	37.41	46.75	4.51	.20					26.58		

Analyses of coal from east-central Carbon County, Wyo.—Continued.

AIR-DRIED SAMPLES—Continued.

No.	Geologic horizon of coal.	Thickness of coal represented by sample.	Locality.	Laboratory No.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Percentage of water to be added to convert to sample as received.	Calorific value. Calories.	Calorific value. B. T. U.
		Ft. in.														
49	"Upper Laramie."	5	Walcott, 11 miles north of, NW. ¼ NE. ¼ sec. 2, T. 22 N., R. 84 W.; upper part of bed of undetermined thickness; surface sample.	3924	10.69	40.00	40.97	8.34	0.43	.....	.....	.....	.....	23.00	.....	.....
50		4	Hanna, 11 miles northeast of, sec. 35, T. 24 N., R. 81 W.	3780	10.12	35.70	48.13	6.05	2.41	5.73	60.53	1.73	23.55	6.16	6,040	10,873
51		4	Hanna, 11 miles northeast of, NE. ¼ SE. ¼ sec. 33, T. 24 N., R. 81 W.	3781	8.29	36.66	48.34	6.71	2.91	.....	.....	.....	.....	4.60	.....	.....
52		4	Same	3779	8.88	35.92	46.10	9.10	3.11	.....	.....	.....	.....	4.60	.....	.....
53		5	Hanna, 4 miles north of, NW. ¼ NW. ¼ sec. 31, T. 23 N., R. 81 W.; surface sample.	3822	9.80	35.16	52.20	2.83	.58	.....	.....	.....	.....	8.58	.....	.....
54		6	Como, 2 miles west of, SW. ¼ NW. ¼ sec. 32, T. 23 N., R. 80 W.	3736	14.49	35.63	47.54	2.34	1.00	.....	.....	.....	.....	13.38	.....	.....
55		6	Como, 2 miles west of, SE. ¼ NW. ¼ sec. 32, T. 23 N., R. 80 W.; upper part of 12-foot bed; surface sample.	3738	10.16	38.65	47.25	3.94	.91	.....	.....	.....	.....	10.13	.....	.....
56		6	Same; lower part of 12-foot bed; surface sample.	3737	12.64	35.41	48.94	3.01	.68	.....	.....	.....	.....	9.65	.....	.....
57		3 6	Hanna, 1 mile southwest of, SE. ¼ NW. ¼ sec. 24, T. 22 N., R. 82 W.; part of bed just below Hanna No. 2.	3616	10.15	42.83	41.14	5.87	.46	.....	.....	.....	.....	3.41	.....	.....
58		8	Hanna, lower bench of No. 2 seam	3610	9.18	43.67	40.34	6.81	.39	5.12	61.19	.96	25.53	2.56	6,205	11,169
59		8	Hanna, upper part of middle bench of No. 2 seam.	3611	10.00	41.80	43.55	4.65	.24	.....	.....	.....	.....	2.67	.....	.....
60		7	Hanna, prospect on No. 2 seam; sample represents middle bench.	3617	9.98	42.03	43.27	4.72	.23	.....	.....	.....	.....	3.52	.....	.....
61		5	Hanna, prospect on seam between Nos. 1 and 2, SW. ¼ sec. 17, T. 22 N., R. 81 W.	3615	9.54	44.36	39.84	6.26	.57	.....	.....	.....	.....	2.67	.....	.....
62		5 3	Hanna, middle bench of No. 1 seam 19 to 25 feet thick.	3612	9.31	43.50	42.93	4.26	.34	.....	.....	.....	.....	2.15	.....	.....
63		6 2	Same; middle bench of No. 1 seam	3613	9.00	43.11	43.46	4.43	.30	.....	.....	.....	.....	3.20	.....	.....
64		7 3	Same; middle bench of No. 1 seam	3614	9.30	43.55	42.51	4.64	.34	.....	.....	.....	.....	3.41	.....	.....
65		5	Hanna, lower part of top bench of No. 1 seam	3605	8.07	41.93	42.85	7.14	.50	5.41	64.07	1.29	21.58	2.24	6,420	11,556
66		9 4	Same; middle bench of No. 1 seam	3606	8.29	43.30	41.01	7.40	.40	5.42	63.71	1.33	21.74	2.25	6,338	11,408
67		4	Same; bottom bench of No. 1 seam	3607	9.82	42.59	41.15	6.43	.45	5.67	63.85	1.01	22.58	1.42	6,288	11,319
68		5	Same; upper part of middle bench of No. 1 seam.	3608	8.06	44.23	41.47	6.24	.52	.....	.....	.....	.....	1.94	.....	.....
69		8	Same; middle bench of No. 1 seam	3609	8.64	41.71	42.34	7.31	.40	.....	.....	.....	.....	2.25	.....	.....

COMPARATIVE VALUE OF COALS.

The coals of this field range from poor to high-grade bituminous. They are as a rule bright, brittle, and noncoking. The best coals in the area are found in the Mesaverde formation, which contains the high-grade coals of the Routt County, Colo., field. These Mesaverde coals are not so good as the Benton coals of Uinta County, Wyo., mined at Cumberland, Diamondville, and Frontier, and are perhaps inferior to the coal at Rock Springs, Wyo. The coals of the "Upper Laramie," extensively mined at Carbon and Dana, are distinctly inferior to the Cumberland and Rock Springs coal, though superior to much of the coal of Laramie age in northeastern Wyoming and eastern Montana. The coal mined at Carbon was rather dirty, and the much cleaner coal at Dana proved so light that in the forced draft of the railroad locomotive it nearly all went out of the smokestack, covering the cars with showers of sparks. After several years, in which it suffered many disastrous car fires, the railroad was forced to abandon the use of coal from this mine. The Hanna coal is now extensively and satisfactorily used in the locomotives of the Union Pacific Railroad.

HISTORY OF DEVELOPMENT.

Coal was found in this area by Frémont in 1843 on Platte River, near the mouth of Sage Creek, at the point now known as Coal Bluffs.[a] In 1856 Lieut. F. T. Bryan, of the topographic corps of the United States Army, surveyed a road from Fort Riley to Bridger Pass. He was accompanied by H. Engelmann, geologist, and they reported coal not only on Platte River but north of the present village of Elk Mountain, near Medicine Bow River. Bryan reports that on August 18, 1856, they encamped for a few days on an island in Platte River, "to rest our animals and burn coal for the forge."[b] The coal beds opened at this time were mined in a desultory way by emigrants and by the Overland Stage Company, whose stage ran across the southern portion of this territory from the summer of 1862 until a short time after the completion of the Union Pacific Railroad.

Regarding the commercial development of coal in this region, George R. Black, superintendent of the Union Pacific Coal Company, states:

> The first mines opened in Carbon County, Wyo., and worked to any extent, were opened by this company in 1868 at and near the town of Carbon, the last one being abandoned in 1902. There were seven of them. While the coal is not of the best, it is quite certain the mines in that vicinity would still be working had not the main line of the Union Pacific Railroad passing through Carbon been vacated and taken

[a] Frémont, J. C., Rept. Expl. Exped. Rocky Mts. in 1842, and to Oregon and North California in 1843 and 1844, Washington, 1845, p. 126.

[b] Thirty-fifth Cong., 1st sess., House Ex. Doc., vol. 2, No. 2, 1858, p. 462.

farther to the north, where it passes through the Hanna coal. The mines at Dana, Carbon County, were opened in 1889 and abandoned in 1891 on account of the coal sparking too badly lor locomotive use. Hanna mines were opened in 1890 and are still in operation.

ECONOMIC CONDITIONS.

Coal-mining operations in Carbon County are at present conducted almost wholly for the purpose of supplying coal to the Union Pacific Railroad, it being stated that of the yearly output of the Hanna mines, 350,000 to 400,000 tons, 90 per cent or more is consumed by the railroad. The natural commercial market for coal from this section is limited on the east by Omaha, on the west by Rawlins, on the north by the Black Hills, and on the south by Denver. The western outlet is to a large degree blocked to-day by the higher-grade coals of Sweetwater and Uinta counties. At Denver the Carbon County coals come into competition with the Colorado coals, at Omaha with the Interior basin Carboniferous coals, and at the Black Hills with the Newcastle and Sheridan coals.

During 1906 the Hanna mines shipped three or four carloads of dust a week (including all that passed through a ⅜-inch screen) to brick-manufacturers in the neighborhood of Omaha. This dust is mixed with the brick clay and is reported not only to aid in the proper burning of the brick, but to result in decreasing the weight of the finished product.

The only prospective local demand for coal is in connection with the development of the metalliferous deposits in the surrounding ranges, and in this respect the coal is something of an untried quantity. The iron deposits in the Seminoe region are very favorably situated with reference to coal deposits, and with railroad facilities will undoubtedly be developed. It is not anticipated that the coal will make high-grade coke. The development of the precious-metal deposits in the Seminoe and Ferris mountains promises some day to make a local fuel market. The Encampment region is at present supplied with coal from the field which lies just west of the Sierra Madre, but with the completion of the railway from Walcott to Encampment easy transportation of coal from the central Carbon County field will be afforded.

COAL OF LARAMIE BASIN, WYOMING.

By C. E. SIEBENTHAL.

The western portion of the Laramie Basin is occupied largely by shales and sandstones which include several beds of coal. This coal has been mined to a small extent for local use and may in future have greater economic importance. The beds are not well exposed, for much of the region is overlain by Quaternary and Tertiary deposits, so that the extent and stratigraphy of the coal-bearing rocks could not be fully ascertained. The coal beds range in thickness from a few inches to 6 feet or more and occur at several horizons. They appear, however, to be irregular in their distribution, in many localities giving place to carbonaceous shale or thinning out entirely.

One of the first mines in Wyoming was opened by the stage company in 1865, near the old overland trail crossing Rock Creek. The coal was used for blacksmithing in the vicinity of the opening and also carried to other places for the same purpose.

On Rock Creek the Diamond Cattle Company has an opening in sec. 7, T. 19 N., R. 78 W., in 6 feet of coal. The product in 1904 was 200 tons, which sold at $2 a ton.

The massive sandstone of Pine Ridge is overlain by a bed of coal which has been opened in a number of localities and at one place mined somewhat extensively. The easternmost opening on this bed is in the SE. ¼ sec. 7, T. 20 N., R. 75 W., on the continuation of Pine Ridge and just east of the old location of the Union Pacific Railroad, 2 miles northeast of Harper. The coal bed is reported to have a thickness of 5 feet. Nothing could be learned as to the amount mined or the quality of the coal.

Another bed of coal has been prospected a mile northwest of Harper station, at a horizon several hundred feet above that of the Pine Ridge coal, but apparently the results were not satisfactory, for no mining was done.

Coal shows at intervals along Pine Ridge west of Harper, and it was worked to a small extent in the SE. ¼ sec. 16, T. 20 N., R. 76 W. Here the coal has about the same thickness and quality as in other openings on this bed. The dip of all the outcrops in this area is to the south at angles of 10° to 15°.

Coal is exposed near the middle of the north side of sec. 21, T. 20 N., R. 77 W., dipping southward at an angle of 5° to 8°. It is more than 7 feet thick and appears to be a bright, clean coal. Apparently it is at a horizon several hundred feet below the coal bed in Pine Ridge. Coal is reported 1 mile north of this place in the bluff on the north side of Rock Creek. It is associated with a heavy white sandstone which forms a short ridge similar to the main Pine Ridge. The beds dip to the north, as they are on the north side of the Rock River anticline. This coal is believed to be at the same horizon as that in Pine Ridge.

The following section is reported in a well on the Empire ranch on Dutton Creek, in the NE. ¼ SW. ¼ sec. 27, T. 19 N., R. 77 W. It was sunk for Judson Sutphin & Co. in 1889.

Log of well at Empire ranch.

	Feet.
Sand and gravel	43
Soapstone, sand, and gravel in layers 10 to 25 feet thick	332
Sandstone with two small beds of coal	60
Soapstone	40
Coal	8
Sandstone	13
Slate	4
Coal	8
Slate	2½
Coal	7½

Doubtless the coal beds reported in this well are those mined 2½ miles farther northwest. The coal borings from this well were analyzed by M. Delafontaine in 1890, with the following results:

Analysis of coal borings from well at Empire ranch.

Specific gravity, 1.51.

Water (at 212° F.)	4.84
Volatile matter; bright, long flame	37.10
Fixed carbon	50.54
Ash, light-fawn color	7.52
	100.00

The coal is noncoking. The large amount of ash appears to be due to some slate fragments intermixed.

In the NE. ¼ sec. 18, T. 19 N., R. 77 W., is the abandoned Terry Fee mine, the "Dutton or Cooper Creek mine" of the early reports. The coal worked here is said to have ranged from 6 to 7 feet in thickness and was a good bright coal, burning with much white ash but no cinders. The roof is of white sandstone with a few inches of shale just over the coal. The dip as measured from present exposures is 8° E. The workings extend into the hill 400 to 500 feet, but the mine has long been abandoned. It is claimed that beneath this coal bed

and separated from it by 8 feet of shale there is another bed 7 feet thick. This is in accord with the succession reported in the log of the Empire ranch well, located 2½ miles farther southeast.

Several outcrops of coal are reported 2 miles northeast of the Terry Fee mine, in sec. 4, T. 19 N., R. 77 W., in the valley of Coalbank Creek. The Monarch mine, which is worked from time to time, is situated in the SW. ¼ sec. 8, T. 19 N., R. 77 W. The coal was found to be 5 feet thick and dips south of east at an angle of about 4°. The coal appears to be of good quality. The roof is of shale and stands well. The entry was driven about 200 feet into the hill, and several rooms were turned off from it. The chief market for the product of this mine and that of the Terry Fee mine was for local use on ranches and in the town of Laramie.[a] A production of 500 tons, which sold at $2 a ton, was reported in 1904.

Coal outcrops near the center of sec. 20, T. 19 N., R. 77 W. The deposit is 2 to 3 feet thick and consists of several 8-inch to 10-inch beds of coal separated by bone. The dip is 15° SE. This bed appears to be at a somewhat higher horizon than the coal of Pine Ridge and possibly may be correlated with the unsuccessful prospect a mile northwest of Harper station.

An anticline trends due south from the mines above mentioned, forming sharp north-south ridges in the vicinity of Cooper Creek Cove. In the southeast corner of sec. 17, T. 18 N., R. 77 W., on the east side of this anticline, a heavy white sandstone outcrops with a dip of 40° E., which probably is the same bed as that which constitutes Pine Ridge. No coal, however, has been reported in the vicinity of this sandstone.

About 3 miles farther southwest, on the west side of this anticline, in the NE. ¼ sec. 6, T. 17 N., R. 77 W., coal outcrops along the road. It dips to the west beneath the ridge and may be either one of the coals above the sandstone of Pine Ridge. It is reported that coal outcrops appear at intervals along this line to Centennial Valley, but none of them were definitely located.

In digging a deep well at Mill Brook coal was encountered at 300 feet in two beds, one 6 feet and the other 3 feet thick.

The following are the available analyses of coal from this region:

Reported analyses of coals in the Laramie Basin.

Locality.	Water.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
Brown mine, Dutton Creek	11.25	36.85	45.00	6.00	1.13
Do	11.85	34.65	47.30	6.20	1.25
Chase mine, Mill Creek	14.50	34.50	44.75	6.25	1.03
Rock Creek mine	14.40	34.90	39.70	11.00	.....
Rock Creek mine, 1904	11.50	32.40	49.70	6.40	.....

[a] Trumbull, L. W., Coal resources of Wyoming: Bull. Univ. Wyoming, No. 7, 1905.

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COAL FIELDS OF THE DANFORTH HILLS AND GRAND HOGBACK IN NORTHWESTERN COLORADO.[a]

By Hoyt S. Gale.

LOCATION.

The coal fields of the Danforth Hills and the Grand Hogback are situated in the northwestern part of Colorado, in the counties of Routt, Rio Blanco, and Garfield. The territory here described is only a part of a much larger field, the Colorado portion of which has hitherto been frequently referred to as the Grand River coal field.

The Danforth Hills field lies north of White River, west of the White River plateau, south of Axial Basin, and east of the valley of Strawberry Creek and its extension toward the north. This valley is fixed as the western limit to the coal field because the coal-bearing strata dipping in that direction pass beneath it to so great a depth that they can not be considered as workable beyond this line. The Grand Hogback is a long monoclinal ridge lying mainly between Grand and White rivers, containing a relatively narrow belt of the outcropping coal strata which forms the southern extension of the Danforth Hills field. It crosses White River near Meeker, Rio Blanco County, extends due south from this point for about 20 miles, and then southeast for a similar distance, crossing Grand River at the town of Newcastle.

A westward extension from the Danforth Hills coal field north of White River lies along the southern flanks of the Yampa Plateau, or Blue Mountain, as it is locally known, reaching across the State line into Utah, beyond which comparatively little is known of the district as a coal field.

ACCESSIBILITY.

The valley of Grand River is at present the principal route by which travel and commerce reach northwestern and western Colorado from the east. It is now the route of the only railroads in Colorado

[a] The present paper is a preliminary report of an investigation conducted in the summer of 1906. The members of the field party were Arthur K. Adams, Albert L. Beekly, Ralph D. Crawford, and the writer. A more complete report containing a detailed contoured map of the coal fields will be published later as a bulletin of the United States Geological Survey.

approaching the coal fields here described. A projected line of the Denver, Northwestern and Pacific Railway passes through Routt County, and is now (spring, 1907) in process of construction from Middle Park by way of Gore Canyon across to the Yampa Valley, with apparently every likelihood of completion in the near future, at least as far as Steamboat Springs. This road, if constructed down Yampa River, will open up a large coal field. A great part of the Danforth Hills and lower White River coal fields will, however, even then be almost as far removed from routes of transportation as they are at present from the railroads on Grand River. The only commercial developments of any considerable extent lying within the field of this report are those at Newcastle and east and southeast of that point, all of which are reached by branch lines from the railroads on Grand River. Among these producing localities may be mentioned the Newcastle, South Canyon, Black Diamond, Pocahontas, Midland, Sunlight, Spring Gulch, and Coalbasin mines.

STRATIGRAPHY.

AGE OF COAL-BEARING ROCKS.

The coal beds occur in a series of sandstones and sandy shales that were mapped by the geologists of the Hayden Survey as the combined Fox Hills and Laramie groups of the Cretaceous. In the reports of the early investigators statements are made to the effect that no definite distinction can be made between the strata of these two formations and that the limits of the groups of strata as then defined were purely arbitrary and were made for the purpose of applying a classification adapted to other fields. The investigations in the Yampa coal field in 1905 [a] led to the conclusion that the subdivisions previously made could not be applied to the sequence of rock formations that occur in that field, and names proposed by Whitman Cross [b] for a similar sequence of Cretaceous beds in the San Juan Mountains region were adopted. These are as follows:

Upper Cretaceous....	Laramie formation.
	Lewis shale.
	Mesaverde formation.
	Mancos shale.
	Dakota sandstone.

South of the anticlinal axis which separates the Yampa basin from the Danforth Hills coal field the sequence of formations including the coal-bearing rocks apparently does not correspond to that of the Yampa field. While two distinct coal-bearing formations, the Laramie and the Mesaverde, are present in the Yampa field, separated

[a] Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: Bull. U. S. Geol. Survey No. 297, 1906.

[b] Description of the La Plata district: Geologic Atlas U. S., folio 60, U. S. Geol. Survey, 1899.

by a thick body of shale, there appears to be but a single series of strata containing coal beds in the southern field, and the evidence at hand points strongly to the equivalence in age of this single series with the older of the coal-bearing formations developed farther north. There can be but little question that the base of the coal-bearing strata in the Danforth Hills field and the base of the Mesaverde formation in the Yampa field are of equivalent geologic age, a conclusion based on the evidence of the fossils which these strata contain and the almost unmistakable structural relations as shown in Axial Basin, where the coal-bearing strata of the two fields are separated by an interval of only 3 or 4 miles across an anticlinal valley.

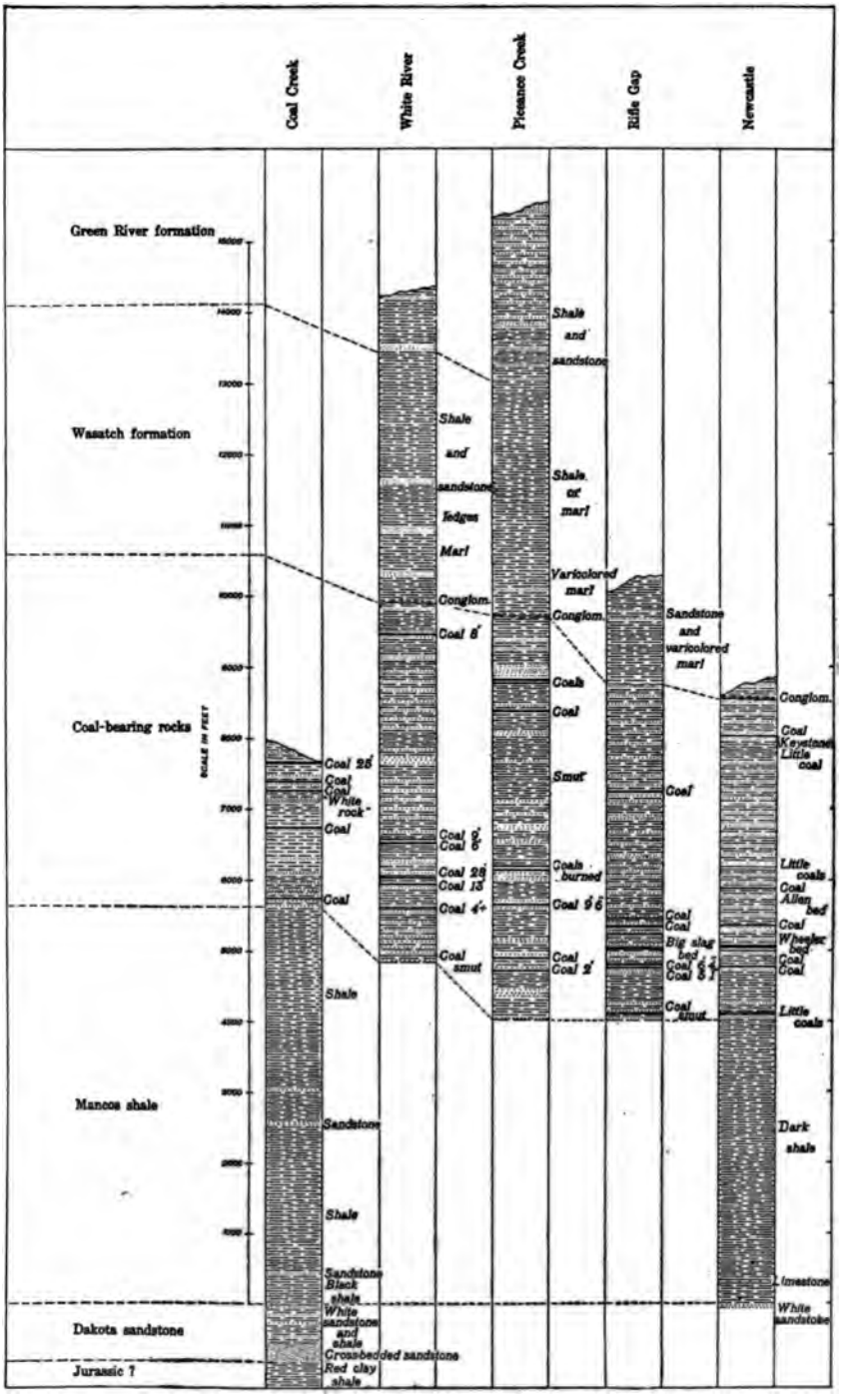
The question as to what constitutes the Laramie formation has long been a source of doubt and dispute. As stated above, the geologists of the Hayden Survey mapped the upper part of the strata of the Danforth Hills and Grand Hogback as of Laramie age. A few fossils were collected during the present investigation that seem to corroborate this earlier determination, as based on the definitions that were then accepted of the Laramie formation. The fact remains, however, that the coal-bearing rocks in the Danforth Hills and Grand Hogback are, for all practical purposes, a stratigraphic and lithologic unit without any recognized break or unconformity.

THE COAL-BEARING ROCKS.

The coal-bearing strata of the fields here discussed are distinct in character from both the overlying and underlying formations. They are massive ledge-making sandstones, together with thinner-bedded sandstones and sandy shales and coal beds. This group of strata usually forms ridges or mountains because the sandstone members offer relatively greater resistance to erosion than either the overlying or underlying shale. The coal-bearing rocks attain a thickness of approximately a mile.

Details of the stratigraphic sections vary from place to place, as do also the thickness and quality of individual coal beds, but a few general characteristics are found to persist in or dominate certain horizons, although all the minor characteristics vary greatly in detail. These features are illustrated in a set of measured stratigraphic sections taken in various parts of the field (Pl. XV).

The base of the coal-bearing rocks is in general sharply defined by the lowest conspicuous sandstone ledge, but in places there is a transition from the prevailing sandy rocks above into shaly strata below. In the present mapping the base of the coal-bearing group of rocks is drawn at the horizon of the lowest sandstone in the main escarpment that characterizes the outcrop of these beds where they face the valley formed upon the underlying shale. The scattering beds of sandstone that occur below the main escarpment show as minor and



MEASURED STRATIGRAPHIC SECTIONS OF DANFORTH HILLS AND GRAND HOGBACK COAL FIELDS, COLORADO.

separate ridges within the valley area. A good example of one of these outlying ridges extends northeastward from Meeker, lying parallel to the principal escarpment front.

The lower 800 to 1,500 feet of these sandstones and shales is more prominent as a ridge maker than the upper members of the coal-bearing strata, but in most localities the majority of the principal coal beds are grouped immediately above that horizon. In the vicinity of Axial Basin the base of the principal group of coal beds is marked by a massive white sandstone which may be readily traced in outcrop along the ridges as a conspicuous white ledge. This is locally referred to as the "white rock" and is apparently a very persistent stratum around a large part of the Danforth Hills.

Coal beds almost invariably show above the "white rock," either as weathered streaks of carbonaceous material or more generally as bands of reddened and baked rock or slag, where the coal has been burned. Higher in the series the coal beds are scattered irregularly, and they vary from place to place so that individual sections show great variations in the number and grouping of the coal beds. The massive sandstone ledges are by far the most conspicuous features, in many places masking by their débris the intervening strata that are composed of weaker rocks.

The coal-bearing rocks appear to merge into the shale or marl of the supposed Wasatch beds above. Scattering sandstone beds occur among the varicolored beds of clay or marl overlying the coals, and many of these are so similar to the coal-bearing rocks as to be indistinguishable from them. There is, however, a very persistent bed of coarse conglomerate or loose bowlders near the top of the coal-bearing strata and below the varicolored beds of the supposed Wasatch, which probably marks an unconformity in the beds—an erosional time break during the deposition of the sediments. The conglomerate is therefore assumed to mark the boundary between the two formations, or, in fact, between Cretaceous and Tertiary strata.

The accompanying table is a summary of the probable correlation, measured thicknesses, description, and topographic expression of the groups of strata which occur in or immediately adjacent to the coal field, arranged in the order of their geologic age.

Stratigraphic groups of the Grand River and White River region, Colorado.

Age.	Formation or group.	Thickness.	Description of strata.	Topographic features.	Fossils.[a]	Economic value.
		Feet.				
Tertiary (Eocene).	Uinta of King and Hayden; "Browns Park" of Powell.	(?)	Sandstone and less consolidated sandy beds, in many places coarse; gritty and calcareous and of white color, with some layers of gravel.	Forms sandhill country, rolling prairie and low ridges or minor peaks. The sandstones are locally exposed as ledges, but usually as clear-white sandy banks, sparsely vegetated with sagebrush, cedar, and piñon. Typically exposed in Axial Basin around Juniper Mountain and in the sandhills between Craig and Lay.	*Physa*, reported by the Hayden Survey; many vertebrate bones reported from this general region.	Placer gold near Lay.
	Marked unconformity.					
	Green River of Hayden, King, and Powell.	2,400+	Sandstone ledges, especially near the base, with shale intervals predominating. In its upper part almost entirely composed of dense fine or sandy clay shale.	Usually forms escarpment bluffs and the long, gentle back slopes of the plateau country. Stream valleys characteristically eroded in deep, narrow canyons. The Roan or Book Cliffs form the best example of these rocks.	*Unio*, *Viviparus*, and *Goniobasis* reported by the Hayden Survey; vertebrate bones also reported.	Gilsonite and related hydrocarbons.
	Wasatch of Hayden; "Vermillion Creek" of King; "Bitter Creek" of Powell (in part).	4,000±	Clays and clay shales, rather commonly variegated in brightly banded and conspicuous colors, as pink, brick-red, vermilion, yellow, drab, brown clear white, or coal-black. Contains pebble beds of perfectly rounded jasper or siliceous material such as colored vein quartz and flint. Conglomerate or bowlder bed near base.	Universally represented by low prairie or valley lands, at many places scarred by badlands washes and gulches. Cactus Valley, on Grand River, and Strawberry Valley, north of White River, are good examples. Usually covered with sagebrush or greasewood except in the barren washes.	*Viviparus*, *Melania*, *Goniobasis*, *Unio*, *Physa pleromatis* White; also bones of vertebrates including *Coryphodon* reported by the King and Hayden Survey; crocodile tooth of Tertiary type, fish scales, and fragments of bone, probably mammalian, found in the present survey.	Agricultural lands where water for irrigation is available.
	Probable unconformity.					

Cretaceous.	Probable unconformity.					
	Laramie and Fox Hills of King and Hayden; probably equivalent to Mesaverde of the Yampa coal field report.	5,000±	Sandstone, sandy shale, and coal beds. Much of the sandstone is massive and ledge making, white or iron stained in color, in places baked to more brilliant colors, as red and yellow, by burning of coal beds. Many coal beds somewhat irregularly distributed through the entire thickness.	Forms hogback ridges and rugged hilly country, dissected by sharply cut canyons and gulches. Usually forms topographically distinct features bordered by valleys on either side formed on the overlying and underlying shale formations. The principal examples are the Danforth Hills and the Grand Hogback.	Upper half: *Ostrea glabra* var. *arcuatilis* Meek, *Anomia*, *Corbicula occidentalis* M. and H.?, *Tulotoma thompsoni* White. Horizon indefinite: *Callista*?. *Anomia micronema* Meek, *Modiola*, *Odontobasis*?. Lower portion near base: [b] *Goniomya americana* M. and H., *Liopistha* (*Cymella*) *undata* M. and H., *Tellina* sp., *Lucina* sp., *Pinna* sp., *Mytilus subarcuatus* M. and H.?, *Inoceramus sagensis* Owen, *Cardium speciosum* M. and H., *Inoceramus cripsi* var. *barabini* Morton, *Corbicula cytheriformis* M. and H., *Ostrea glabra*, *Syncyclonema rigida* H. and M., *Avicula linguæformis* E. and S., *Baculites ovatus* Say, *Baculites compressus* Say.	Coal.
	"Colorado" of Hayden and King; "Sulphur Creek" as mapped by Powell in this region: Benton, Niobrara, and in part Pierre; Mancos shale of the Yampa coal field report.	5,000±	A thick mass of dark drab or gray shale, containing lenticular members of sandstone and near its base one or more beds of limestone and sandstone. At the base is a black compact or slaty shale, usually containing many fish scales. Coal is reported near the base in Yampa River Valley.	Forms open valleys and broad parks and basins, with a few minor hogback ridges. The parks are very extensive: among them may be mentioned Axial Basin and Agency Park.	Lower part: *Ostrea congesta* Conrad?, *Prionocyclus* sp., *Inoceramus dimidius* White, *Baculites gracilis* Shumard, *Scaphites warreni* M. and H., fish scales, *Inoceramus fragilis* H. and M., *Prionotropis* sp.	Agricultural lands where water is available; limestone.
	Dakota sandstone ("Henrys Fork" of Powell).		Massive and in general markedly cross-bedded ledge-making sandstone, quartzite, and conglomerate, with some shale intervals. In its lower part or possibly belonging to the underlying Jurassic (Morrison or Gunnison formation) is a very constant bed of dark-green compact clay, with cuboidal fracture, also accompanied in many places by bright-colored banded shale.	High, sharp hogback ridges, with elevated, broad dip slopes, usually covered with quaking aspen and scrub oak.		Limited use as building stone; source of artesian water.

Below this occurs a great thickness of older rock strata which are not, however, directly concerned with the area of this report.

[a] Determination of invertebrates collected by the present survey by Dr. T. W. Stanton.
[b] The marine fossils of this list are all from the lower part and in most cases from beneath the workable coals.

STRUCTURE.

UINTA AND GREEN RIVER BASINS.

The coal fields of northwestern Colorado are contained in two broad structural basins or depressions of the rock strata, surrounded by areas of older rocks which are relatively uplifted. The northern of these two is the Green River Basin, the greater part of which lies in Wyoming, but which extends into Colorado to the headwaters of Yampa River. The Uinta Basin is separated from the Green River Basin by the Uinta Mountain anticlinal axis, which reaches eastward through Axial Basin into the White River plateau and the western spurs of the Rocky Mountain system. The Uinta Basin lies south of the Uinta Mountains, extends to the Rocky Mountains and their foothills on the east, and is terminated on the south by the uplifts of the La Sal Mountains and the San Rafael Swell. It extends westward to the Wasatch Range in Utah. The Uinta Basin in Colorado includes an area of approximately 7,000 square miles.

These two basins outline the dominant geologic structure of nearly the whole of northwestern Colorado. They are in the form of broad synclinal folds or troughs, narrowing to an apex toward the southeast. Within this State their longer axes are approximately parallel, extending from southeast to northwest. The coal-bearing rocks outcrop in practically continuous rims around the borders of the basins where they have not been buried by later formations, and the strata dip toward the interior of the basins, probably extending to great depths beneath the younger and overlying deposits. Thus the coal fields actually available are limited for the most part to the territory adjacent to the outcropping coal beds.

That part of the eastern rim of the Uinta Basin which was examined during the past year extends from the Danforth Hills southward to Grand River. In the Danforth Hills the exposure of the coal-bearing beds is broad, for their outcrop is repeated by minor folds. South of the Danforth Hills the coal strata extend in a narrow outcrop of steeply inclined beds known as the Grand Hogback from White River to Grand River, a distance of 43 miles. South of Grand River the Grand Hogback continues in a southeasterly and southerly direction, disappearing as a monoclinal ridge in the high and rugged district of the West Elk Mountains. Coal croppings may be followed with some brief interruptions southward from the vicinity of Glenwood Springs on Grand River across the main divide to the tributary valleys of Gunnison River. Near the well-known anthracite locality at Crested Butte the strata lie nearly horizontal, forming the extreme southeastern apex along the longer axis of the Uinta Basin.

MINOR FOLDS OF THE COAL-FIELD STRATA.

The Danforth Hills field is composed of a complex system of folds by which the strata are bent into irregular anticlines and synclines. The beds lie tilted against the older rocks on the north, east, and south and plunge beneath the younger formations toward the west. On all sides except the west the edge of the coal field is marked by a much-dissected monoclinal ridge presenting an escarpment front toward the surrounding valleys and, where not further complicated, either a gentler back slope toward the interior of the field or a more gradual rise toward the higher summits.

In the Danforth Hills the present divide between White and Grand rivers follows approximately the crest or axis of the principal anticlinal fold, in which the strata dip more steeply on the southern than on the northern limb. Toward the northwest end of this region erosion has removed the coal-bearing rocks on the northern limb of the fold, and only the southern half remains, forming a monoclinal ridge that constitutes the westward extension of the Danforth Hills coal field. Along the crest of this principal anticline erosion has removed the upper members of the coal-bearing rocks, and some of the deeply eroded canyons or gulches in that part of the district are cut through the lower principal group of coal beds, as indicated on the geologic map (Pl. XVI).

On the north side of the divide the spurs reaching out toward Axial Basin and Yampa River extend across a broad syncline parallel and coordinate with the anticline of the main divide. A long, gentle northerly dip of the strata is abruptly terminated near Axial Basin by the sharp upturn of the beds at the edge of the Axial Basin anticline.

These folds, which may be traced the length of the field, are complicated by cross folds, giving to the whole the effect of minor domes and basins. A depression of this kind follows the valley of Morgan Creek, producing an inclosed minor basin, with correspondingly uplifted areas bordering it on all sides. Sharp folding of the strata in the northeastern extremity of the field near Thornburg Mountain has produced another narrow structural basin inclosed by steeply dipping beds on all sides but the west. These subordinate structures are difficult of description and can best be interpreted from the dips of the strata as plotted on the map.

Probably the most marked and readily recognizable structural feature of the Danforth Hills coal field is the synclinal axis extending from east to west across the upper valleys of Sulphur, Curtis, and Coal creeks. This axis is apparent in the V-shaped ledges that show in the divide west of the stage road in the vicinity of the Harp & Moulton ranch on Curtis Creek. The open valley lands of upper

Sulphur and Curtis creeks and the Ninemile Draw are eroded from the weaker shaly strata that outcrop along the axis of this syncline. Farther east the fold crosses Coal Creek and terminates at the southeast end of the Danforth Hills field. To the west the two limbs of the Sulphur Creek syncline spread sharply at Strawberry Valley, the northern limb forming the western border of the Danforth Hills field, the southern limb continuing across White River as a monocline, already described as the Grand Hogback ridge.

FAULTS.

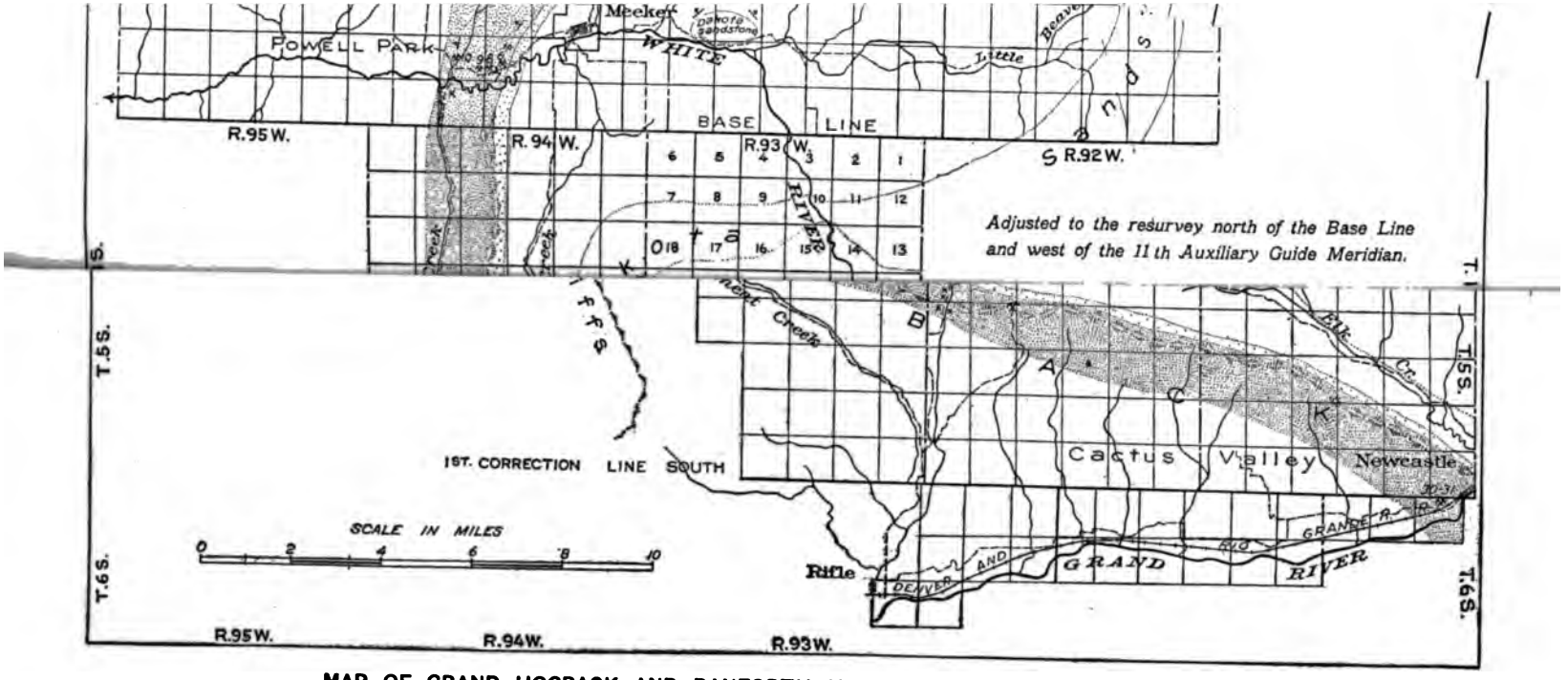
The structure of this region is affected only in a very subordinate way by faults. In the absence of readily distinguishable beds or horizon markers among the coal-bearing strata, and by reason of the similarity of the various members of this group of strata, minor slips or dislocations within the field may easily have been overlooked. Although some suggestions of possible faults were noted during the progress of the field work, in but a single case did the evidence seem clear enough to be unquestionable. In that case, however, the fault did not appear to affect the coal field, occurring west of it and influencing only the Tertiary rocks north of the Keystone ranch. Many minor slips of the beds near the surface are encountered in prospecting or mining the coal, but these are too local to be recognized as structural features, and too small to be shown on the map.

COAL.

AREAL EXTENT OF THE COAL FIELDS.

As explained in the descriptions of the great structural basins, the coal fields that are likely to prove commercially valuable are limited very closely to the areas of actual outcrops of the coal-bearing rocks, for the dips of the strata toward the centers of the basins are generally steep, and in most parts they doubtless carry the coal beds to great depths a short distance back from the outcrop. Such conditions prevail especially along the eastern margin of the Uinta Basin, which is here described as the Danforth Hills and Grand Hogback coal fields.

The area of the Danforth Hills is very nearly 300 square miles and this may be considered as practically the extent of that coal field. As has been stated, the lower thousand feet or so of the coal-bearing group of sandstones and shales do not usually contain valuable coals, and the recognized outcrop of these rocks is distinguished by a separate pattern on the geologic map (Pl. XVI). However, as these lower strata are known to contain some coal, they may properly be considered as a part of the coal field.



MAP OF GRAND HOGBACK AND DANFORTH HILLS COAL FIELDS AND VICINITY.

The Grand Hogback coal field is limited to a narrow belt between White and Grand rivers which includes an area of probably not much more than 75 square miles.

THICKNESS AND NUMBER OF COAL BEDS.

As explained under the heading "Stratigraphy" (p. 266), the group of rock strata that contains the coal is approximately a mile in thickness, and many beds of valuable coal are found in one position or another within this mass. Both the total number and the thickness of the individual beds vary from place to place along the outcrop, as may be observed in the thickening or pinching out of the beds where they can be traced. In only two localities is anything like a complete measurement of the coals now obtainable. One of these, at Newcastle, on Grand River, is particularly favorable for the measurement of what is supposed to be the maximum thickness of coal beds, as it contains the thickest single coal known in the whole field. The other, on White River below Meeker, may be taken as representative of the stratigraphic section of the field in its total quantity of coal, which is somewhat less than that of the Newcastle section. Similar sections are exposed at other localities in the various stream gaps along the Grand Hogback, but the lack of development makes it impossible at the present time to measure the coals.

The section across the Grand Hogback at Newcastle is probably the most completely prospected in the field. Some mines of considerable extent have been operated at this place under the management of the Colorado Fuel and Iron Company. The measurements given for the coals of this locality are taken from the statements of the chief engineer of that company,[a] for all but one of the mines are now abandoned and wholly inaccessible. The locality as a mining camp is known to be dangerous, as much trouble has been experienced with explosive dust and gas and spontaneous combustion of the coal. Mines on all the large beds on the north side of Grand River have been abandoned on account of fire, which up to the present time has proved entirely beyond control. The following is a statement of the thickness of the different coal beds at Newcastle:

Thickness of coal beds at Newcastle.

	Feet.		Feet.
"C seam"	5	"E seam"	18
"Anderson seam"	8	"F seam"	4
"Allen seam"	20		
"D seam"	5	Total workable coal	105-108
"Wheeler seam"	45-48		

[a] Hosea, R. M., The Newcastle mines, Colorado: Colliery Engineer, vol. 17, 1897, pp. 377-382, 425-429.

The thickness of the stratigraphic intervals separating these beds is shown on Pl. XV (p. 266). The Wheeler coal is approximately 1,000 feet from the base of the formation, and the Allen is approximately 1,000 feet above the Wheeler. The only coal now worked on the north side of Grand River is a bed known as the Keystone, which is somewhat higher than any in the section detailed above, and which is only 22 to 24 inches thick. The Keystone bed is 4,000 feet stratigraphically above the base of the formation, and with the exception of two smaller beds, is the highest known coal bed. The beds of the Newcastle section dip southwestward at angles ranging from 50° at the base of the formation to 25° at the Keystone mine.

Coal in the section across the Grand Hogback on White River below Meeker has been developed mainly to supply the small demand for domestic use in that vicinity. The beds dip to the west at angles ranging from 31° to 68°, and most of the thicker coals are exposed by a series of prospects along the north side of White River. The following coals were accessible when visited and were measured in the present investigation:

Thickness of coal beds exposed on White River below Meeker.

	Ft.	in.
Lion Canyon, upper entry	5	8
Lion Canyon, W. B. Blythe coal mine	8	5
A. H. Adams mine, 3 benches, not including bone	8	5
Old Meeker bed, A. H. Adams property	5	10
F. W. Fairfield property, west entry	6	3
F. W. Fairfield property, middle entry, upper bench	9	8
F. W. Fairfield property, middle entry, lower bench	9	+
F. W. Fairfield property, east entry (old Major bank)	13	+
Mrs. Grace H. Adams property, prospect	3	3
Mrs. Grace H. Adams property, mine	4	1
	73	7

Without doubt a considerable number of workable coals that are not included in the foregoing list occur in the White River section. It is therefore safe to assume a minimum thickness of 75 feet as representing the workable coal of this section.

Though all the coal-bearing strata may be found in regular sequence in a small portion of the field where the beds are so steeply tilted as to bring the uppermost down to water level (a condition fulfilled for the most part only along the western margin of the field), the remaining and greater part of the coal field is underlain only by the lower members of the formation, the upper strata having been worn away. Synclines and basins generally retain a larger number of coal beds below water level than regions uplifted and dissected by canyons or broader valleys. The geologic map shows several areas within the Danforth Hills, from which it seems clear that nearly all the valuable coals have been removed.

Fortunately for the economic development of the Danforth Hills field, the principal coal beds occur low in the formation and many of the important coal beds remain where even a great thickness of strata has been removed. Thus many of the thick coal beds outcrop at the surface along the ridges and gulches in the interior of the field, and by reason of their light dips may prove readily accessible for development.

The best-known examples of thick coals in these localities are two beds that have been opened on Spring Creek Gulch near and south of Axial post-office. These measure 25 and 27 feet of excellent coal, a total of over 50 feet exposed, with indications of a considerable number of other workable beds near by.

DETAILED DESCRIPTIONS.

A systematic review of all the localities examined or measured will be included in a report of this investigation to be published later. It has been found necessary to limit the descriptions in this preliminary report to a brief mention of the more important properties. These are treated in the order in which they were examined in the field, the numbers indicating the mine and prospect localities on the maps (Pls. XVI, p. 272, and XVII, p. 290).

Nos. 2-4, Lay, Routt County.—The localities numbered 2, 3, and 4 are in a group of coal entries situated about a mile south to southeast of Lay post-office, in Routt County. These coal properties are in the west end of the Yampa coal field and are described in the report on that field,[a] although they were not sampled during the field work of that investigation. One of these properties was sampled by R. C. Hills, and the analysis published in 1893.[b] The following measurements were made where the samples were obtained:

Section of the 20-foot coal bed at Lay (No. 2).

	Ft.	in.
Coal without partings	9	9
Shale, carbonaceous	1	3
Coal, apparently free from partings (lower 5 feet 7 inches sampled)	10	6
Shale, carbonaceous.		
	21	6

Section of the Peacock coal bed at Lay (No. 3).

	Ft.	in.
Coal left as roof, thickness reported	1	6
Coal, mined	5	2
Coal, bony, pyritiferous		4
Coal, mined	2	
	9	

[a] Bull. U. S. Geol. Survey No. 297, 1906, p. 63.

[b] Coal fields of Colorado; Mineral Resources U. S. for 1892, U. S. Geological Survey, 1893, p. 365.

Section of the Sweeney coal bed at Lay (No. 4).

Shale.	Ft.	in.
Clay, white, kaolin-like	1	±
Coal	3	10
Bone	1	
Coal	4	
Bone	1	7
Coal, thickness reported, not measured	4	
	15	5

No. 5. Collom mine, Axial, Routt County.—The Collom mine, on Spring Creek, 1½ miles south of Axial post-office, is probably the best-known coal bank in the northern part of the Danforth Hills. The coal bed is very thick, measuring, as nearly as could be determined, 24 feet 5½ inches, with a single half-inch bony seam 16 feet 3 inches from the base. The coal lies nearly flat, dipping lightly to the south and east, and is an exceptionally solid, bright, black shiny coal. It breaks with an irregular conchoidal fracture, and is clean to handle, being apparently very free from smut or dust. It shows an excellent analysis as compared with other coals of this part of the field and an exceptionally low amount of ash. The following is a section measured at the mouth of the mine:

Section at Collom mine near Axial (No. 5).

Shale.	Ft.	in.
Coal	8	6
Shale or bone		½
Coal	16	3
Shale	3+	
Total coal bed	24	9½

The Collom bed is several hundred feet stratigraphically above that of the W. H. Miller bank (No. 16 of this list), but a close estimate of this interval could not be obtained. The mine has been worked in a broad, high entry, so that wagons from neighboring ranches are loaded at the face, the teams being driven in and turned around in the mine.

No. 6. Mrs. G. H. Adams property, Meeker, Rio Blanco County.—The first entry on the public road west of Meeker is in the NE. ¼ SW. ¼ sec. 28, T. 1 N., R. 94 W., and is the property of Mrs. Grace H. Adams. Entries have been made on two of the lowest workable beds that have been recognized in this region. The following section was measured at this place.

Section on Mrs. Grace H. Adams's property, west of Meeker (No. 6).

	Ft.	in.
Shale, blue clay	2+	
Coal, weathered outcrop	1	6
Shale or blue clay, lenticular bed		7+
Coal, weathered outcrop	2	10
Sandstone, single stratum	4	
Coal, weathered outcrop	3	3
Shale, brown	2	8
Sandstone, massive	1	10
Coal (sample No. 6)	4	1
Floor not exposed.		
	22	9

The principal development is an old mine on the lowest coal noted in the above section. This consists of a slope running down in an approximately north direction for about 200 feet at an inclination of about 15°. The strata dip 36° N. 60° W.

Northeast of the entry just described, about 200 feet along the strike, a coal bed, probably corresponding to one of those measured in weathered outcrop in the preceding section, has been opened by a prospect slope for a distance of 80 or 100 feet. The coal is at least 3 feet thick, the base of the bed being covered by débris that was sliding down the entry. The roof of this bed is poor, being composed of a weak blue clay shale. A local report states that this bed is coking coal, but it was not sampled, and, so far as is known to the writer, no satisfactory tests to determine its coking quality have yet been made.

Nos. 7 and 8. F. W. Fairfield property, Meeker, Rio Blanco County.—There are three entries on the Fairfield property on White River, just west of the Adams property above described. This is a 40-acre tract in the NW. ¼ SW. ¼ sec. 28, T. 1 N., R. 94 W., and is the property of F. W. Fairfield, of Meeker. These three entries start near the stage road on the 40-acre tract south of the one just mentioned. The easternmost entry is situated at the mouth of a very short gulch, or side valley, and is marked by a considerable slack pile and an old bin and tipple. The bed here opened is 175 to 200 feet stratigraphically higher than those on the Adams property, a considerable thickness of massive white sandstone intervening between the two beds. The entry runs in nearly on a level along the strike of the coal bed, which here has a direction of N. 25° E., the dip being 36° W. The bed itself is composed of several benches of coal separated by bone or clay, the total thickness reaching at least 14 feet. The following is the section taken at this mine:

Section at easternmost entry on Fairfield property, west of Meeker (No. 7).

	Ft.	in.
Shale, sandy, or soft sandstone.		
Sandstone, flaggy	1+	
Coal, upper bench	4	11
Bone, with coal streaks		8
Coal, middle bench	5	3
Parting, flinty, fire clay		3
Coal, lowest bench to mine floor	2+	
Total coal bed measured	13	1+

No sample for analysis was taken, because of the uncertain condition of the mine roof. The coal is largely slacked on the mine dump, but some large lumps still remain.

A few hundred feet west of the mine above described a slack heap of considerable size marks two more entries on the same 40-acre tract in the face of the steep bluff close to the public road. These entries are close together, and open various benches of coal which might be considered as parts of a single large bed. The beds lie 75 or 100 feet higher stratigraphically than those last described. In the eastern of the two entries the strike of the beds is N. 17½° E. and the dip 42° W. About 110 feet from the mouth of the entry the drift forks, an opening to the left passing over through the roof of the lower bed or bench into another bed of almost the same thickness above. The following is a section showing the thickness of these beds:

Section of coal beds on Fairfield property, west of Meeker (No. 8).

	Ft.	in.
Coal	9	8
Clay, white, sandy	2	11
Coal	9+	
	21	7+

The measurement of the lower bench of coal was taken in the right-hand drift. This showed 9 feet of clear coal with no partings, but the measurement does not include a portion of the coal bed left up as a roof, nor some coal that still remains on the floor. The entry on the upper bench in this mine runs in about 540 feet beyond the point at which it turns off from the lower entry, a total length of about 650 feet from the mouth of the mine. A good measurement obtained in this portion of the mine showed 9 feet 8 inches of coal with a 1¼-inch clay parting at a distance of 1 foot 11 inches below the roof. The floor is hard white sandy clay that forms the roof of the coal bed below. A considerable amount of coal has been taken from this mine.

The mine next to the west is on a coal bed close above the double bed just described, the entrance being about 100 feet farther west. This drift runs in 430 feet along the strike of the coal bed, which is recorded as N. 20° E. at this point, the dip being 37° W. The coal is 6 feet 3 inches thick, with a coal floor which could not be measured. The roof is sandstone. Three inches of coal at the top of the bed is much slickensided and the coal is much jointed across the bedding.

A local report states that coal beds aggregating 50 feet in thickness have been opened on this property, but this statement could not be verified at the time of visit, although it is undoubtedly true that several thick beds do occur.

No. 9. A. H. Adams property, Meeker, Rio Blanco County.—The next group of entries west of the Fairfield property is on a 40-acre tract of coal land belonging to A. H. Adams, of Meeker. This is the SE. ¼ SE. ¼ sec. 29, T. 1 N., R. 94 W. The eastern entry is now abandoned and caved, but it was originally worked from an entrance passing through a dwelling house close to the public road. This coal bed is said to be the first one opened for use at the old Meeker Indian agency, although a similar claim is made for the so-called "old Government bank" on Coal Creek. A measurement made at the outcrop of this bed gave 5 feet 10 inches of coal without partings or bone. The coal was apparently clean and hard and of good quality. A massive sandstone 15 feet or more in thickness, immediately overlying the bed, should afford a good roof. The floor is bony coal. The strike is N. 8° E. and the dip 42° W. It may be noted that the strata become more steeply inclined toward the west. Mr. Adams makes the following statement:

> The longest of the three tunnels penetrates the coal a distance of about 325 feet. About 5,300 cubic yards of coal have been mined from this bed. An analysis of the coal by Mr. Noble showed 53 per cent fixed carbon. It is of uniform thickness and shows no bone or slate and very little ash. There are no important beds between my property and the Lion Canyon mine. There are several smaller ones, the largest of which I have any knowledge being on my property and measuring about 28 inches, lying about 175 feet above the west bed.

The western coal bed on the Adams property is estimated to be about 130 feet stratigraphically above the "old Meeker seam." This entry is at present marked by a whim and small wooden-frame tipple. It runs down a short slope and ends in a small room, the whole being less than 100 feet in length. Several very massive sandstone ledges occur just above the coal bed, the immediate roof being a few inches (3 ±) of blue clay shale. The strike of the rock in the entry is N. 17° E., but no satisfactory determination of the dip was obtained. The following is a detailed section taken in the mine.

Section in west entry on A. H. Adams's property, west of Meeker (No. 9).

	Ft.	in.
Coal, good	5	1½
Clay, hard		1
Coal, good	1	4
Bone, black, flinty, not constant		[a]5
Coal, apparently good	1	
Coal or bone, soft, flaky	1	
Bone, or carbonaceous shale floor.		
Total coal bed	8	11½

The measurements given above do not remain constant, even in this small mine. The coal is apparently similar in quality to the others that were sampled in this vicinity. (See analyses, pp. 297–299.) Lump coal that was said to have been standing in the mine car five months was checking and breaking, but the lumps still retained their original shape.

West of the Adams mine no other coal beds were noted among the outcropping ledges for a distance of a little over half a mile, as far as the Lion Canyon mine. This interval is occupied by a number of huge cliff-making sandstones, dipping westward at angles ranging from 50° to 60°, and interbedded with several rather thick beds of shale.

No. 10. W. B. Blythe property, Meeker, Rio Blanco County.—The Lion Canyon mine is the property of W. B. Blythe, whose house stands a short distance back from the road in front of the mine entrance. The mine is located in the NE. ¼ SW. ¼ sec. 29, T. 1 N., R. 94 W., and is opened on an 8½-foot bed of coal. The entry runs in straight along the strike for a distance of 1,140 feet, giving a good determination of N. 11° E., with dips ranging from 55° to 65°, or an average of about 63°. In running the entry the coal has been worked out to a height of 25 to 40 feet in the steeply dipping bed. The entry is then braced above with stulls and lagging. The mine is equipped with a good 1-ton car and track running the length of the entry. The entry is of such grade that the car is hauled in by means of a burro, and when loaded runs out by gravity. At the mouth is a substantial wooden-frame tipple. This was the only property in the district just described that was being worked at the time of visit, the price of coal being $2 loaded at the mine, or $3 delivered in Meeker, 4 miles away.

On both sides of the entrance to the mine huge bare sandstone ledges stand up like ramparts. The following section was measured at the mine, the thickness of the coal being taken at the face where

[a] Maximum measurement.

the sample was taken, and the rest of the measurements near the mine entrance:

Section at Lion Canyon mine, Meeker No. 10.

	Ft.	in.
Sandstone, very massive	75±	
Coal (sampled)	8	5
Clay, hard (weathers readily to a friable bluish shale)	25±	0
Sandstone, massive, white (good building stone)	40±	

This coal has a local reputation for being the hardest and in other ways the best for domestic use of those mined about Meeker. It has a dull, spotted appearance which causes it to be described by local residents as "sorry looking." One point mentioned in its favor is that it burns without soot, but it is also admitted that the coal does not stand well, slacking quickly when exposed to the weather. Its analysis shows a lower fixed carbon and higher moisture content than others obtained from freshly worked faces in the mines of this vicinity.

Just west of the entrance to the Lion Canyon mine another bed shows in an old opening, measuring 5½ feet in thickness. Mr. Blythe claims to have opened several small beds still higher than this which he says are 2 to 3 feet in thickness, and are the uppermost coals in the section.

Nos. 11 and 12. Keystone basin, Deepchannel Creek, Routt County.—A single coal bank has been opened on the western margin of the Danforth Hills district to supply coal for domestic use at the Keystone ranch, 27 miles northwest of Meeker. This bank is situated in the gulch northeast of the Keystone reservoir, in the E. ½ sec. 30, T. 4 N., R. 95 W. An entry has been driven in 90 feet or more, penetrating a bed of coal at least 7 feet thick, with a sandstone roof and apparently without partings. All of the coal was much broken and slickensided. According to the analysis it is rather below the average, probably on account of its somewhat excessive moisture content, which may be largely the result of its weathered condition.

The valley of Strawberry Creek is practically without water for agricultural purposes and consequently is almost without settlement, there being but two ranches located along it north of the settlement in Powell Park on White River. For this reason there has been little demand for fuel and no development of the many coal beds that outcrop in nearly all the gulches that drain the western slope of the Danforth Hills.

Nos. 13 and 14. Morgan Gulch, Routt County.—Morgan Gulch is a broad, open valley on the north slope of the Danforth Hills about 7 miles west of Axial post-office. There is one ranch in this gulch, the property of David Morgan, of Axial, whose house is situated about a mile from the southern edge of Axial Basin. Mr. Morgan has opened

a small coal bank in a side gulch a quarter of a mile west of his house. The following section was measured at the mine:

Section at Morgan mine, 7 miles west of Axial (Nos. 13 and 14).

	Feet.
Sandstone	7
Shale	3
Coal	10
	20

The coal is much broken, very soft, and slacks very readily, going to pieces after only a week's exposure to sun and air. There is some evidence that this mine is on a block that has slumped or slid down the gulch side, and this may account for the shattered condition of the coal. No sign of the slip has yet been encountered in the mine, but this relation is indicated by the attitude of the beds in the hillside above. The coal dips 6° S., as measured in the mine. It is opened for use at the Morgan ranch only.

For a number of miles south of the Morgan mine the strata are very nearly horizontal, and, as described in the chapter on structure, this district is one of relative depression of the coal-bearing strata, so that a considerable thickness of the coal-bearing beds underlies the whole territory. The rocks rise gradually to the south toward the main divide and also to the west, with the result that most of the thicker beds soon pass above water grade and are found on the ridge tops only along Maudlin and Temple canyons. Morgan Gulch has an extensive drainage area in the Danforth Hills, and all of this territory south of the edge of Axial Basin is, without any reasonable doubt, underlain by valuable coal beds at workable depth.

No. 15. Box Elder Gulch, Routt County.—West of Morgan Gulch are two smaller valleys, in the eastern of which, known as Box Elder Gulch, a single large coal bed was opened, but has now caved so as to be partly inaccessible. The following section was measured at this place:

Section at coal prospect in Box Elder Gulch (No. 15).

	Feet.
Sandstone	7
Shale	2
Coal	5
Coal, clayey	1
Coal (base not reached)	4
Total coal	10+

No. 16. W. H. Miller entry, Axial, Routt County.—An abandoned drift on a thick coal bed is situated on Spring Creek almost exactly 1 mile south of Axial post-office and half a mile or so north of the

Collom mine, already described. This drift is said to have been opened by W. H. Miller, to supply coal for domestic use. The entry consists of a simple prospect drift running in a distance of 120 feet from the entrance. According to a measurement made as carefully as the present exposure would allow, the bed is 26 feet 10 inches thick. It dips 10° SW. The following section was measured 15 feet from the face of the entry:

Section in W. H. Miller mine, 1 mile south of Axial post-office (No. 16).

	Ft.	in.
Clay roof.		
Coal, good	3	
Coal, dirty, powdery		4
Coal, good	5	
Bone		1
Coal, not exposed in the mine.		
	8	5

The above section represents only a portion of the lower half of the bed. Most of the coal of the entry has been taken from below the 4-inch parting. The horizon of this parting is festooned with a fringe of long, white fibers of epsomite or magnesium sulphate.

No. 17. James entry, Routt County.—The James coal bank is situated on Spring Creek, 4 miles south of Axial, on the west side of the stage road. It consists of an entry 100 feet in length showing coal at least 8 feet thick with a coal roof and bone floor. Shale overlies the whole bed. The coal bed dips about 8° S. 20° E. The coal is hard, with a high luster, and shows no partings. The mine seemed not to be regularly worked, although the coal was fresh and the analysis shows it to be of good quality and similar to the other good coals of this part of the field.

No. 18. Shafer mine, Routt County.—The only development along the northern part of Milk Creek Canyon is at the Shafer mine, just south of Axial Basin and a couple of miles east of Axial post-office. This has evidently been worked to supply the few ranches in the immediate vicinity in Axial Basin. The following rough measurements were made, the exposures not permitting more careful determination:

Section at Shafer mine on Milk Creek south of Axial Basin (No. 18).

	Ft.	in.
Shale roof.		
Coal, minimum thickness	12	
Bone		2
Coal, minimum thickness	2	
Coal floor.		
	14	2

This coal is hard and apparently of very good quality. A sandstone dike was observed in the mine cutting the coal bed, nearly

perpendicular to the bedding. Similar dikes were also noted in the Coryell mine on Grand River. A sample representing the upper 7 feet 6 inches of the bed was taken within 6 feet of the face of the mine. The entry runs down a slope on the dip for 25 feet, and a drift then swings to the left at a lighter pitch, turning up grade slightly in the last 25 feet of a total length of about 125 feet. This bed is probably about 100 feet above the "white rock," with another heavy sandstone stratum some 50 feet above the coal. Another coal bed is prospected in a small tributary gulch north of the mine, its position being stratigraphically between the Shafer bed and the "white rock."

There has been much burning of coal along the outcrops in the vicinity of the Shafer mine and above the "white rock," and there are doubtless a number of other valuable coal beds in this locality. A few small coals were noted occurring stratigraphically below the "white rock." Many outcrops of coal and much baked rock indicating the presence of other beds are to be seen along the valley of Milk Creek through its entire course between the Shafer and Wilson entries, but at no place are any of these beds known to have been opened so as to show the value of the coals.

No. 19. J. F. Wilson mine, Rio Blanco County.—Several prospect drifts have been opened at the upper end of Milk Creek canyon in the coal field, 2 or 3 miles below the Thornburg battle ground. Of these the only one that was in condition for sampling was an entry on the property of J. F. Wilson, of Thornburg, in the NW. ¼ SE. ¼ sec. 29, T. 3 N., R. 92 W. Three openings have been made close together on the same coal bed, of which the northernmost is the only one worked at present. The coal appears to be of good quality, very hard, withstanding the action of the weather. The following section was measured at this place:

Section at the J. F. Wilson bank in Milk Creek Canyon (No. 19).

	Ft.	in.
Shale.		
Coal	2+	
Shale, carbonaceous	1	
Coal	11	1
Shale, carbonaceous	2	
Coal	2+	
	18	1+

The bed dips 15° N. 80° W. In the middle of the three openings, the coal, although it had not been worked for a long time, seemed fresh and hard, and a good face was exposed.

A quarter of a mile north of the Wilson entries, also on the west side of Milk Creek, there are two prospects that appear to have been formerly worked, but are, at present, completely caved at the entrance.

The following measurements were made, but this section is very incomplete:

Section in Milk Creek canyon, one-fourth mile north of the Wilson mine.

Shale.	Ft.	in.
Coal	1	
Shale, carbonaceous		10
Coal, at least	5	
	6	10

The coal bed dips 5° N. 80° W. The second of the two entries opened a coal about 30 feet lower, but was totally inaccessible. Both of these beds are several hundred feet higher in the series than the Wilson bed. The latter is roughly 400 or 500 feet above the "white rock."

No. 20. Coal Creek, Rio Blanco County.—On the west side of Coal Creek, in sec. 30, T. 2 N., R. 92 W., almost directly opposite the "Transfer," Gilbert Wesson has opened a prospect drift showing a fine bed of bright, hard coal over 25 feet thick. The prospect is on Government land which is withdrawn from entry pending the completion of the resurveys. Nearly the whole thickness of the bed is exposed at the mouth of the entry, but the height of the coal and the timbering of the entry made a good measurement of the bed impracticable. The coal bed dips N. 75° W. at an angle of about 22°. The entry is situated structurally at the flattened nose of a westward-pitching synclinal trough, the end of that described on page 271 as the Sulphur Creek syncline. Outcropping coal beds at or near this horizon extend southward and, crossing a narrow spur or ridge, are again prospected in the banks of Ninemile Draw. This bed and those closely associated with it extend toward the north in outcrop along the ridge face approximately parallel to the public road beyond Yellow Jacket Pass, and may be the same coal as that opened just north of the pass and also at the Wilson mine in Milk Creek Canyon.

At the entrance to the Wesson mine an ash bed indicates that the lower part of the bed has been partially burned, but this burning extends in only a few feet. The present entry starts in near the middle of the bed, leaving much coal above and below as both roof and floor. The following is a section measured at the face of the mine, but includes only a portion of the total thickness of the bed:

Section in Wesson mine, Coal Creek (No. 20).

	Ft.	in.
Coal roof		(?)
Coal, good	3	
Coal, dirty seam		2
Coal, good	1	6
Coal, dirty seam		2
Coal, good	4	3
Coal floor.		
	9	1

By a measurement of the whole stratigraphic section exposed near the locality of the "Transfer" (see Pl. XV, p. 266), the Wesson bed is estimated to be 2,000 feet above the base of the coal-bearing rocks. Here, as at many other points throughout the field, the "white rock," a prominent massive white sandstone ledge, occurs in the coal-bearing rocks just below the principal group of workable coal beds. The Wesson coal bed lies about 500 feet, stratigraphically, above this ledge. Below the ledge several indications of coal were noted, one bed having been prospected to a depth of 60 feet or more, but, as elsewhere in this basal portion, the coal appears to be of comparatively little value. Above the white sandstone ledge at least two other beds are exposed below the Wesson bed, and possibly others may be obscured along the débris-filled bottom of Coal Creek.

Above the Wesson mine the canyon wall rises steeply to a height of 600 or 700 feet and the rocks are fairly well exposed. A few sandstones outcrop, but these are not prominent as ledge makers, showing chiefly where they have been hardened by the burning of coal beds. In such places they form cliffs of brecciated rock of bright-vermilion to brick-red color, interspersed with patches of unaltered white sandstone. These ledges are usually much broken up, being jointed both parallel to and across the bedding. As elsewhere noted, the coal beds rarely show in outcrop, having been almost universally burned, and leaving only slag, cinders, and reddened rock at the surface of the ground. Coal Creek appears to be an exceptionally favorable locality for the commercial development of the thick coal beds that undoubtedly occur at that place. These coals dip westward, with flattening pitch, and almost certainly underlie at workable depth a large territory extending along the axis of the Sulphur Creek syncline. An advantage of the Coal Creek locality as a point of access to this structural basin lies in the fact that the beds here have more moderate and uniform pitch in the direction of the synclinal axis than anywhere along the sides of the basin.

Nos. 21 and 22. Sulphur Creek, Meeker, Rio Blanco County.—A working mine and several prospect entries are situated in the valley of Sulphur Creek about 4 miles north of Meeker, in the NE. ¼ NE. ¼ sec. 10 and in the SW. ¼ sec. 3, T. 1 N., R. 94 W. These are reported to be the property of T. D. Riley and Arthur Burnham, both of Meeker. The mines are on the P. P. Harp ranch. There are, in all, four entries, two on each side of the gulch. The two southernmost are apparently of the same or nearly the same horizon, opening coals on opposite sides of the valley. The bed at the principal mine is at least 7 feet thick, and the following section was measured 470 feet from the entrance:

Section in main entry, Sulphur Creek mine, north of Meeker (No. 21).

	Ft.	in.
Sandstone, massive	20	
Bone	1	
Coal	1	3
Bone, sandy		1
Coal		8
Bone, sandy		1
Coal	4	
Bone floor.		
Total coal bed	7	1

The coal is hard and rather tough. At the face of a side entry about 200 feet farther east, 280 feet from the mine entrance, the following section was measured:

Section in side entry, Sulphur Creek mine, north of Meeker (No. 22).

	Ft.	in.
Coal roof (not measured).		
Coal	1	2
Parting, sandy		½
Coal		11
Parting, sandy		½
Coal	3	1
Bone floor.		
	5	3

The mine is equipped with two 1-ton cars and a tipple. It is worked chiefly in the winter time, when the average output is reported as 120 tons a month.

No. 23. Old Meeker mine, Sulphur Creek, Rio Blanco County.—An abandoned and partly caved mine on Sulphur Creek, on the southwest side of the gulch and near the wagon road, is reported to be one of the oldest mines near Meeker. These workings are said to go in approximately 500 feet along the strike of the coal bed, in a direction about S. 20° W. The dip of the bed is 19° to 23° W. The following section was measured in the mine:

Section in old mine on southwest side of Sulphur Creek (No. 23).

	Ft.	in.
Shale roof (poor).		
Coal	1	4
Parting, sandy		½
Coal (sample No. 23)	3	9
Coal floor.		
	5	1½

Sandstone and shale are exposed above the mine, reddened by the burning of other beds of coal.

No. 24. Black Diamond mine, Meeker, Rio Blanco County.—The Black Diamond mine of Meeker is situated in the NE. ¼ SW. ¼ sec. 15, T. 1 N.,

R. 94 W., about three-fourths of a mile northwest of the Pollard mine (No. 25). It is owned by George M. Lord, of Meeker, and the coal, which is known as the "Lord seam," is locally reported to be 22 feet thick. The total measurement of the bed was not obtained, about 8 feet only being exposed in the mine. The following section was measured:

Section in Black Diamond mine near Meeker (No. 24).

	Ft.	in.
Coal roof.		
Coal	3	11
Coal, soft, powdery ("mother coal")		½
Coal	3	10
	7	9½

The dip is recorded as 19° N. 80° W. The drift is 430 feet long. This is said by some persons to be the best coal near Meeker; its analyses, however, are very similar to others of the district.

No. 25. D. Pollard mine, Meeker, Rio Blanco County.—The Pollard mine is situated near the northwest corner of sec. 22, T. 1 N., R. 94 W., being located in part on the 40-acre tract of patented coal land which is the property of D. Pollard, of Meeker. This mine is in a steep, narrow canyon that opens into Meeker Valley near the northwest corner of the townsite about 1½ miles from the town itself. The bed contains apparently good hard coal 5 feet 9 inches thick, with shale roof and shale floor. The strike of the bed is N. 5° E. and the dip 28° W. This bed has been opened on both sides of the gulch, the main entry running in to the north. It was reported that a fault has been encountered on the south side. The following section was measured on the north side of the gulch at the entrance to the main workings:

Section at Pollard mine, Meeker (No. 25).

	Ft.	in.
Sandstone	4	
Shale	3	
Coal	1	8
Shale (reported not constant)	1	1
Coal (base not reached)	5	8
Total coal bed measured	8	5

Several beds of coal are noted above and below the principal one mined, and it is thought that the whole group is approximately the same horizon as that of the Mrs. Grace H. Adams property on White River. The Pollard bed is said to be 60 feet below the Lord bed.

The following section was measured in the mine:

Section in Pollard mine 510 feet from entrance (No. 25).

	Ft.	in.
Sandstone roof.		
Coal	2	9
Coal, pyritiferous		½
Coal	3	4
Sandstone floor.		
	6	1½

A 4-horsepower engine is used to haul the coal up a 250-foot incline, beyond which the drift is driven northward along the strike. The output is reported to be 150 to 190 tons a month during the winter months.

No. 26. Curtis Creek, Meeker, Rio Blanco County.—From Sulphur Creek the outcrop of the lower coal group extends to the northeast and, swinging eastward, crosses Curtis Creek valley about 4 miles distant. One bed has been opened in the Curtis Creek canyon, near the Meeker-Axial stage road, 6 miles from Meeker. This entry is near the line between secs. 29 and 32, T. 2 N., R. 93 W., and is reported to be the property of W. H. Miller. A drift runs in along the coal bed for 70 feet, in which the following measurements were made:

Section at Miller prospect on Curtis Creek, 6½ miles north of Meeker (No. 26).

	Ft.	in.
Shale roof.		
Coal, good	2	3
Coal, dirty		3
Coal, good	1	4
Bone		1
Coal (peacock colors)	1	4
Shale floor.		
	5	3

The beds dip 17° due north. Except for the fact that the bed is much broken by partings, the coal is apparently of good quality, clear, and hard.

No. 27. Spring Creek, Rio Blanco County.—There is an abandoned and caved prospect on upper Spring Creek, about 2½ miles northwest of Ninemile Gap. The coal was much weathered and in poor condition. The bed is overlain by shale and is at least 5 feet thick. There is another prospect in a side gulch a few hundred feet above the one sampled.

Nos. 28 and 29. Rifle Creek, Garfield County.—The McLearn mine on Rifle Creek was the only property in active operation along the Grand Hogback north of Rifle Creek gap, and this and one other property 2 miles southwest of the gap constitute the only working developments along the whole hogback between Grand and White rivers. The McLearn mine is situated in sec. 12, T. 5 S., R. 93 W.

The mine consists of a drift in the eastern face of the hogback, cutting across the basal beds of the coal-bearing rocks in the direction of the dip, striking the coal at a distance of 200 feet. This coal is estimated to be 500 to 600 feet from the base of the sandstone ledges. Side headings are turned off in both directions along the strike of the coal bed, the one to the north penetrating the coal for more than 700 feet. The south heading has been caved by an explosion and is at present inaccessible.

The coal bed is 7 feet 3 inches thick, without bony seams or partings, although a foot or so at the upper or hanging-wall side is softer than the rest and usually breaks up in mining, so that it is lost as slack. The following partly estimated section was taken in the mine:

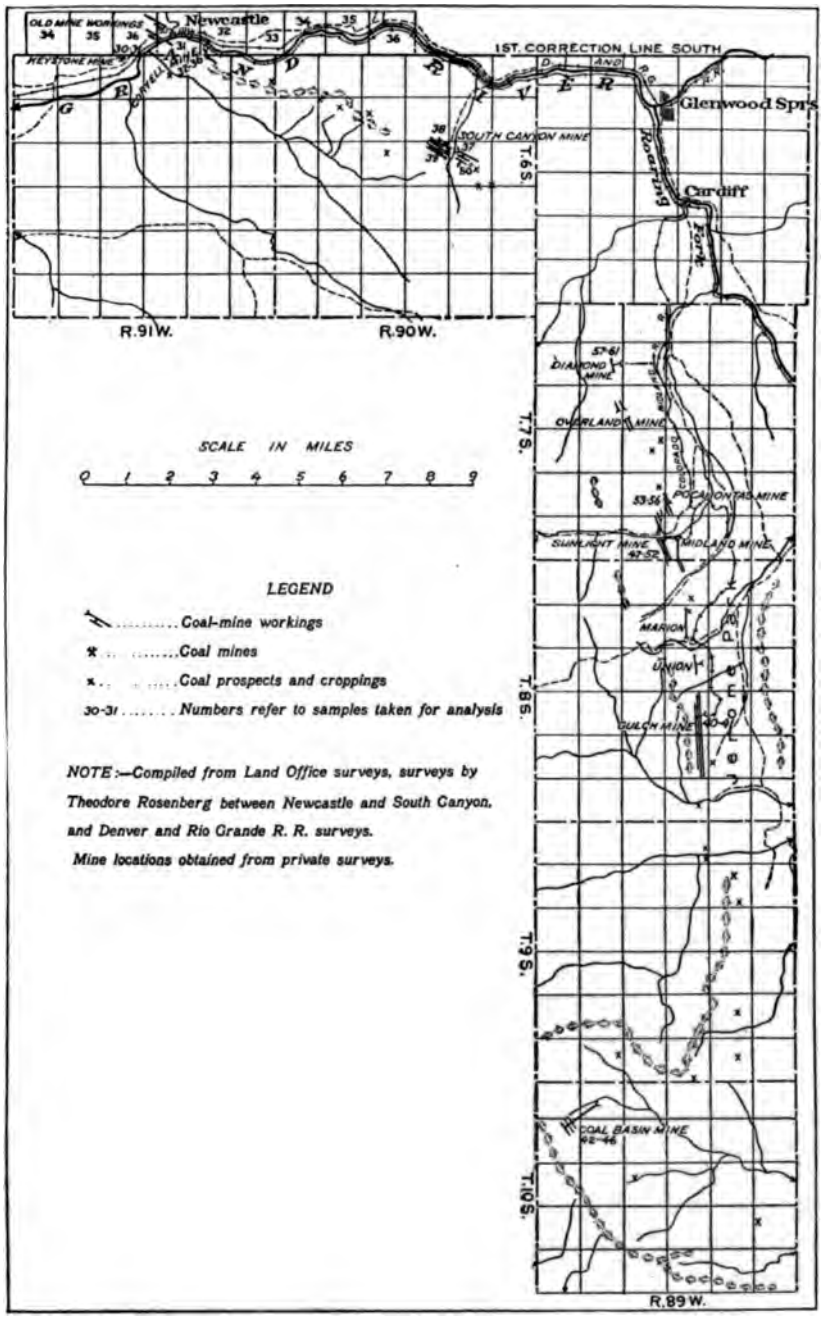
Section in main entry of McLearn mine, Rifle Creek (Nos. 28 and 29).

	Ft.	in.
Sandstone, flaggy (roof).		
Coal (mined)	7	3
Shale, brown, carbonaceous, thin bed at floor.		
Interval, mostly sandstone	10+	
Coal	2	
Sandstone	20	
Coal	2	
Clay, soft, sandy		2
Shale, fine, dark gray	30±	
Sandstone, white, very massive	60±	
Alternating massive white sandstones and shale to entrance of mine.		

The coal is exceedingly dusty, and the dust is dangerously explosive, so that this mine is said to be known locally as the "shotgun" mine.

Nos. 30 and 31. Keystone mine, Newcastle, Garfield County.—The Keystone mine, at Newcastle, was being worked under lease at the time of visit, and is of especial interest as being one of the most extensive developments on a thin coal bed reported in the Rocky Mountain coal fields. The coal bed varies from 20 to 24 inches in thickness, with a roof of hard, compact clay or shale of lenticular character, so that it is said to pinch out and leave in places a roof of hard sandstone, which is the next stratum overlying. The clay roof slacks readily when exposed to the air and where it is thick makes a poor roof, as it drops sooner or later. The floor is a soft carbonaceous shale, which is undercut and the coal falls or is shot down. The coal breaks down in large blocks, with no slack or waste in handling.

The mine consists of a main slope, along which side headings on the upper lifts have been worked out for a considerable distance and abandoned. At present the slope runs to a depth of 500 feet or more. The work being done at the time of visit was on the two headings from the lowest level. The coal is taken out by the long-wall method, the entire bed being removed and the gob or waste being used to



MAP OF GRAND HOGBACK SOUTH OF GRAND RIVER.

Showing coal croppings and developments.

pack the space worked out below the working face. The analyses indicate that the coal is high-grade bituminous, similar to other samples collected near and south of Grand River, and distinctly superior to any sampled in the region north of White River.

Nos. 32 to 36. Coryell mine, Newcastle, Garfield County.—The rather extensive developments on the many thick beds of the Newcastle section north of Grand River have been idle for a number of years, and all machinery and equipment have been removed. A single property known as the Coryell mine, on the south side of the river, half a mile or so east of Newcastle, is now operating under the management of the Coryell Mine Leasing Company of Newcastle, controlled by the Rocky Mountain Fuel Company. It is opened on the Allen bed, the old workings on the Wheeler being caved and inaccessible at this place. The mine consists of a main entry starting in at the base of the hogback below the coal and drifted 600 feet in the direction of the dip, to the point where the coal bed is struck. A side drift or heading turns eastward from this point, and this had penetrated the coal bed a distance of 625 feet at the time of visit (October, 1906). The Allen bed is 14 feet thick and has a southerly dip of about 50°, measured in an upper lift where the whole bed was well exposed. A seam or parting of soft coal of irregular thickness, averaging something more than a foot, occurs from 4 to 6 feet above the floor. This is apparently good coal, but it is badly crushed, has a foliated texture, and yields much dust in handling. The dust is inflammable in this as in other mines of the district, and for this reason the workings are sprinkled regularly to avoid explosions. Plans have been carefully worked out to perfect the ventilation of old and new workings, in order to prevent the accumulation of explosive gas.

The coal bed is cut by a considerable number of sandstone dikes, which have, however, been found only in the lower bench of the coal. They are in all shapes and attitudes in the coal, most of them crossing the bedding more or less and when separated from the coal seem very dense and heavy.

The coal is of excellent quality, as shown by the analyses, comparing very favorably with many representative eastern bituminous coals. It has a low ash and low moisture content and should be an excellent steam coal. The output of the mine was, when visited, about 175 tons a day, of which 90 tons daily are used by the engines of the Colorado Midland Railway, the main track of that road passing close to the entrance of the mine.

Nos. 37 to 39. South Canyon mine, Garfield County.—The mines at South Canyon are situated about a mile south of Grand River, in the valley for which they are named, 7 miles east of Newcastle and about

5 miles west of Glenwood Springs. The developments are in the NW. ¼ sec. 14 and the NE. ¼ sec. 13, T. 6 S., R. 90 W. South Canyon crosses the hogback or "Coal Ridge," and coal beds are exposed on both sides of the valley. On the east side a bed supposed to be the same as the Wheeler at Newcastle is the only one developed; on the west this bed and one other correlated with the "D seam" of the Newcastle section are opened. The beds dip steeply toward the south, the inclination measuring something more than 50°. The Wheeler coal is about 18 feet thick at this place and shows a parting or slip 4½ to 5 feet from the roof. In mining the entry is advanced on the coal below the slip, the upper portion being taken down later. The "D seam" is about 5 feet thick and is locally considered to be better coal than the Wheeler. All the workings are on the room and pillar system. Gas and dust are dangerous, and Wolff safety lamps are used.

On the east the main entry runs in to a distance of 2,650 feet (October, 1906) and serves as a haulage way and air intake. On the west side of the gulch the Wheeler bed is on fire, and the main entry of the present workings is driven in beyond the fire along the D bed, with a crosscut through 87 feet of rock to the unburned Wheeler beyond. An electric tram connects the mines with the tipple on Grand River, where the coal is washed and shipped via the Colorado Midland Railway to Denver and Cripple Creek. The mines have a gravity haul and are self-draining.

Nos. 40 and 41. Gulch mine, Pitkin County.—Gulch, or Spring Gulch, in Pitkin County, is about 21 miles nearly due south of Glenwood Springs and is reached by a branch of the Colorado Midland Railway that leaves the main line at Cardiff. The coal produced is of coking quality, the line separating the coking-coal district from that of poorer noncoking coals to the north being reported as approximately the Pitkin-Garfield county line. The old workings, which have been abandoned for seven years, are on three beds, known as the A, B, and C, and these constitute the lower group. The present developments are on coals about 800 feet stratigraphically higher in the series, known as the Sunshine and Anderson beds. The Sunshine is the lower and ranges from 9 to 14 feet in thickness, averaging about 12 feet. The Anderson bed is about 50 feet above the Sunshine and ranges from 4½ to 6 feet in thickness. The coal beds dip toward the west at an angle of 35°. A number of faults have been encountered in the old workings of these coals, but generally the throw is less than 100 feet. The entrance to the mine is down a slope of 25°, beyond which the entry turns southward along the strike of the rocks. The upper set of workings is extensive, being over a mile in length. From the entrance of the mine cars are let down to the tipple over a gravity plane 1,400 feet long. At the tipple the coal is loaded into railway cars and

shipped to Cardiff, where it is screened, the coarse lump coal being shipped for fuel and the fine coal burned for coke. The output of this mine is reported to be about 500 tons daily.

Nos. 42 to 46. Coal Basin mine, Pitkin County.—The next developments south of Gulch are at Coal Basin, Pitkin County, on a branch of Crystal River, 12 miles west of Redstone and about 40 miles by railroad south of Glenwood Springs. The coal that is now worked is of coking quality. These mines belong to the Colorado Fuel and Iron Company. They are situated in secs. 5, 6, 7, and 8, T. 10 S., R. 89 W. The main haulage way extends in about 2,000 feet toward the southwest, in the direction of the dip, and from this entry a number of side headings have been driven on various levels. A double coal bed has been opened at this locality, the two benches being separated by a parting that ranges in thickness from 2 inches to at least 4 feet. The upper bench is from 7 to 10 feet thick and is the only one mined, the lower part of the bed being dirty and not of coking quality. The rocks have a much lighter dip than at the localities farther north, measurements taken ranging from 12° to 16° W. The strike of the beds is about N. 35° W.

There are many rolls in this mine—that is, inequalities of roof and floor—and a number of faults, all of normal type. The floor heaves rapidly as the coal is taken out and a gang is kept constantly "brushing" the levels and entries—that is, lowering the tracks by cutting the entry deeper as the floor rises. Many props, which are the only timbers used, are buckled and broken. As the mine is very gaseous Wolff safety lamps are used and all of the coal is picked down instead of being shot. Powder is used only in the rock crosscuts.

The tipple is below the entry and this involves a main and tail-rope system of haulage. The cars are of steel and hold 2 tons each. About 100 men are employed at the mine, of whom 55 are miners. The output is said to be 450 tons daily. The entire product is made into coke at Redstone, whence it is shipped to the company's plant at Pueblo.

Nos. 47 to 52. Sunlight mine, Garfield County.—The Sunlight mine is situated north of the properties at Gulch and about 15 miles by railroad south of Glenwood Springs. Four workable beds are exposed. The following section is typical of this locality:

Section at Sunlight mine.

	Ft.	in.
Coal ("D seam")	9	
Shale	25	
Coal ("C seam")	3	
Shale and sandstone	6	10
Shale	9	
Coal ("A seam")	10	
	62	10

The main entry is a drift and runs in a total of 2,500 feet, the first 1,100 feet of which is in the rock along the strike of the beds, that part of the coal bed being on the property of the Colorado Fuel and Iron Company. The A bed is first struck and from it crosscuts are driven to the B, C, and D. The rocks strike N. 10° W. and dip 44° W. The A and D beds are the only ones now worked and all of the coal is used for roasting ore. The coal is said to be noncoking. Naked lights are used, although there is undoubtedly much gas and dust in the mine.

About 800 feet stratigraphically above this lower group of coal beds is an old working on a bed known as the Sunshine, said to be 16 feet thick. This was formerly worked by the Colorado Fuel and Iron Company, but is reported to have proved unsatisfactory as a coking coal.

Nos. 53 to 56. Pocahontas mine, Garfield County.—The Pocahontas mine is situated about a mile north of Sunlight and is the property of the Rocky Mountain Fuel Company. Two beds are worked at this place and are known as the A and D. The main entry is driven in about 2,500 feet. The A bed is reported to be 16 feet thick, but the lower portion contains so much bone that it can not be worked advantageously, only the upper 7 feet being considered of value. The following is a section of the beds exposed at this locality:

Section near the Pocahontas mine.

	Ft.	in.
Coal ("D seam")	12	
Shale	17	
Coal ("C seam")	7	6
Shale	7	6
Coal	1	
Interval	4	
Coal ("B seam")	3	5
Interval estimated	20	
Coal ("A seam")	7	
Shale, bony	9	
	88	5

The strike of the beds at this mine is N. 14° W., and the dip 42° W.

From the entrance of the mine to the tipple there is a straight double-track gravity plane 5,200 feet long. Seven cars are let down at a trip. The output is reported to be about 150 tons daily.

The C bed, which is about 7 feet thick, gave the following measurements:

Section of "C seam," Pocahontas mine.

	Ft.	in.
Shale roof.		
Coal	3	11
Shale	4	
Coal	3	6
Shale floor.		
	11	5

Nos. 57–61. Black Diamond mine, Garfield County.—The next development east of South Canyon is the Black Diamond mine. This is owned by the Empire Coal Company, and at present is leased by the Cardiff Coal Company, of Leadville. It is situated 8 miles southwest of Glenwood Springs. The mine has been lying idle for seven years and is now being reopened. The section is reported to contain seven beds of workable coal. Of these, the lowest is 5 feet thick, and is known as the "Black Diamond seam." An entry made on this bed serves as a main haulage way. Crosscuts are made from the main entry into a 16-foot and a 12-foot bed above. These beds strike N. 27° W. and dip 52° SW. The Black Diamond coal is said to be of the best quality. The mine is not gaseous, and has excellent natural ventilation. A Mitchell tipple and a 5,000-foot tramway are at present under course of construction.

The 16-foot bed is split by a lens of shale, and the following measurements were made of the upper portion, of which the lower 2 feet is very soft:

Section of upper portion of 16-foot bed at Black Diamond mine (No. 57).

	Ft.	In.
Coal	2	2
"Mother coal"		1
Coal	1	10
Parting		2
Coal	5	
	9	3

The lower portion of the 16-foot bed is separated from the upper portion by a locally thick shale parting, which is said to pinch out within a distance of 300 feet. The Black Diamond seam is a 5-foot bed of excellent domestic coal, with no partings.

QUALITY OF THE COAL.

The coal examined and tested is a good grade of bituminous, and the samples taken are thought to be fairly indicative of the average content of the field. North of White River the coal is apparently similar to that occurring in the western part of the Yampa field, and this district comprises the greater part of the available coal of the fields here described. South of White River the coal tested is somewhat higher grade than any other hitherto examined in the northwestern part of the State, with the exception of the anthracite occurring locally in Routt County. Unfortunately no good samples of fresh coal were available along the Grand Hogback for about 30 miles south of White River. The coals that were analyzed from Rifle Creek and from the districts southeast of that point showed a very uniform and in most cases a marked increase in efficiency as compared to those from the districts farther north. The improvement in the quality

the coal toward the south in the Grand River region, as shown by the analyses, may be due, in part, to the more extensive developments of those districts, most of the samples being obtained from a much greater depth and perhaps of fresher coal. On the other hand, there seems, also, to be a marked regional change, the effect on the character of the coal being shown by a decrease in moisture content and a corresponding increase in fixed carbon and volatile constituents. In certain districts local metamorphism from volcanic intrusion seems apparent, as for example, at Coal Basin, where one or more beds of coking coal, high in fixed carbon, comparatively low in volatile matter, and with a very small moisture content, have been produced.

During the progress of this investigation 61 samples of coal were collected from different parts of the field for analysis. The results of the analyses of these samples are given in the following table. As the figures here given express the composition of the samples as received at the laboratory in sealed air-tight cans and also the composition of air-dried samples, they should be directly comparable to most of the analyses that have been previously made of the coals from these localities. All chemical analyses and calorific determinations of samples collected during the progress of this work were made at the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., by F. M. Stanton, chief chemist.

In determining the value of a coal from its chemical analysis, and also in comparing one analysis with another, it is important to know how the sample was taken, how it was treated, after it was obtained, and how the analysis was made, especially the determination of moisture. In this work the samples were all collected and treated according to the following methods of sampling adopted by the fuel-testing plant:

After the face of the coal was cleaned of weathered coal and powder smoke a cut was made across the face of the bed from roof to floor, including all of the benches of coal mined and such impurities as were not removed in ordinary work. This cut was about 3 inches wide and 1 inch deep; the coal obtained from it, amounting to 25 [to 100] pounds, was caught upon an oilcloth [or heavy canvas square] spread upon the floor of the mine so as to protect the samples from water and from admixture of shale and clay fragments that usually abound in such places.

The coal composing the sample was then pulverized and quartered down, according to the generally accepted rules for preparing samples, until a quart sample was obtained, the particles of coal being reduced to a size not much greater than one-half inch in diameter. The sample was placed in an air-tight galvanized-iron can, having a screw top, and the can was hermetically sealed by screwing the top down tight and covering the joint with adhesive tape. The can containing the sample was then mailed to the testing plant. When it reached the chemical laboratory, the sample was at once transferred to a glass jar, in which it was sealed until the time arrived for making a chemical analysis.

By being sealed at the mine the sample reached the chemical laboratory with its moisture content unchanged. Part of this moisture is inherent in the coal and part is extraneous, either derived from

water in the mine or from the atmosphere. In order to eliminate some of the extraneous moisture, the samples, during the first year's work at the testing plant, were exposed to the air after they were pulverized until they reached a fair degree of constancy of weight and then were analyzed. The amount lost during the exposure to the air is noted in the report as "loss of moisture on air drying." This method, however, was found to be unsatisfactory, since the amount of loss depended almost entirely upon the degree of saturation of the air, and this varied greatly from day to day.

Later, when these samples and those from the Yampa field were analyzed, the method was changed, the samples being artificially dried in order to secure greater uniformity of the moisture content, the method being as follows:[a]

In order to make determinations of the loosely held moisture more uniform and definite, a special drying oven has been designed and introduced into the laboratory. In this oven samples of several pounds weight can be dried in a gentle current of air, raised from 10° to 20° above the temperature of the laboratory. In this way the coal is air dried in an atmosphere with a very low dew-point and not subject to large percentage variations, and the results obtained were considerably more concordant.

Analyses of coal samples from Danforth Hills and Grand Hogback coal fields, in northwestern Colorado.

	Lay, 20-foot bed.	Lay, Peacock bed.	Lay, Sweeney bed.	Axial.	Meeker.				
Laboratory No.	3463.	3461.	3462.	3466.	3483.	3482.	3498.	3504.	3502.
Analysis of sample as received:									
Prox. Moisture	14.65	13.31	12.31	11.25	12.53	10.31	9.41	12.00	13.20
Prox. Volatile matter	34.73	35.18	36.17	38.80	31.78	34.86	37.97	40.04	39.02
Prox. Fixed carbon	44.48	46.53	45.40	47.92	50.51	45.23	45.38	45.72	42.35
Prox. Ash	6.14	4.98	6.12	2.03	5.18	9.60	7.24	2.24	5.43
Ult. Sulphur	.99	.90	1.10	.32	1.36	.73	.75	.51	.68
Ult. Hydrogen	5.80	.....	5.75	.....	.....	.....	5.34	.....	.....
Ult. Carbon	60.07	.....	62.72	.....	.....	.....	63.39	.....	.....
Ult. Nitrogen	1.10	.....	1.16	.....	.....	.....	1.23	.....	.....
Ult. Oxygen	25.90	.....	23.15	.....	.....	.....	22.05	.....	.....
Calorific value determined:									
Calories	5,869	.....	6,163	.....	.....	.....	6,291	.....	.....
British thermal units	10,564	.....	11,093	.....	.....	.....	11,324	.....	.....
Loss of moisture on air drying	5.30	4.50	4.00	3.50	4.40	3.20	2.40	3.30	3.20
Analysis of air-dried sample:									
Prox. Moisture	9.87	9.23	8.66	8.03	8.50	7.34	7.18	9.00	10.33
Prox. Volatile matter	36.67	36.84	37.68	40.21	33.24	36.01	38.90	41.40	40.31
Prox. Fixed carbon	46.97	48.72	47.29	49.66	52.84	46.73	46.50	47.28	43.75
Prox. Ash	6.49	5.21	6.37	2.10	5.42	9.92	7.42	2.32	5.61
Ult. Sulphur	1.05	.94	1.14	.33	1.42	.75	.76	.53	.70
Ult. Hydrogen	5.50	.....	5.53	.....	.....	.....	5.20	.....	.....
Ult. Carbon	63.43	.....	65.33	.....	.....	.....	64.95	.....	.....
Ult. Nitrogen	1.16	.....	1.22	.....	.....	.....	1.26	.....	.....
Ult. Oxygen	22.37	.....	20.41	.....	.....	.....	20.41	.....	.....
Calorific value determined:									
Calories	6,198	.....	6,419	.....	.....	.....	6,446	.....	.....
British thermal units	11,156	.....	11,554	.....	.....	.....	11,602	.....	.....
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	20 3	9	7 10	24 11	4 1	21 7	6 3	9	8 5
Thickness of part sampled	5 7	7	5 5	10	4 1	9 8	6 3	6 6	8 5

[a] Bull. U. S. Geol. Survey No. 290, 1906, pp. 29-30.

Analyses of coal samples from Danforth Hills and Grand Hogback coal fields, in northwestern Colorado—Continued.

	Deepchannel Creek.		Morgan Gulch.		Box Elder Gulch, prospect pit.	Axial.			Thornburg.
Laboratory No.	3571.	3569.	3688.	3690.	3689.	3703.	3704.	3707.	3792.
Analysis of sample as received:									
Prox. Moisture	19.21	21.02	15.26	15.37	31.40	14.18	12.01	13.15	10.81
Prox. Volatile matter	34.12	39.32	30.70	35.21	32.66	34.78	35.83	36.44	33.94
Prox. Fixed carbon	40.81	33.58	50.33	43.11	30.91	44.46	47.54	47.54	45.30
Prox. Ash	5.86	6.08	3.71	6.31	5.03	6.58	4.62	2.87	9.95
Ult. Sulphur	.59	.47	.55	.97	.33	.56	.52	.57	.52
Ult. Hydrogen	.....	.....	.....	.....	.....	5.81	5.44	5.48	.....
Ult. Carbon	.....	.....	.....	.....	.....	60.62	63.87	64.12	.....
Ult. Nitrogen	.....	.....	.....	.....	.....	1.01	1.35	1.07	.....
Ult. Oxygen	.....	.....	.....	.....	.....	25.42	24.20	25.89	.....
Calorific value determined:									
Calories	.....	.....	.....	.....	.....	5,838	6,312	6,328	.....
British thermal units	.....	.....	.....	.....	.....	10,508	11,362	11,390	.....
Loss of moisture on air drying	4.40	5.70	6.50	6.20	17.60	6.30	3.40	4.90	3.30
Analysis of air-dried sample:									
Prox. Moisture	15.49	16.24	9.37	9.77	16.75	8.41	8.91	8.67	7.77
Prox. Volatile matter	35.69	41.70	32.83	37.54	39.64	37.12	37.09	38.32	35.10
Prox. Fixed carbon	42.69	35.61	53.83	45.96	37.51	47.45	49.22	49.99	46.84
Prox. Ash	6.13	6.45	3.97	6.73	6.10	7.02	4.78	3.02	10.29
Ult. Sulphur	.62	.50	.59	1.03	.40	.60	.54	.60	.54
Ult. Hydrogen	.....	.....	.....	.....	.....	5.46	5.24	5.20	.....
Ult. Carbon	.....	.....	.....	.....	.....	64.69	66.12	67.42	.....
Ult. Nitrogen	.....	.....	.....	.....	.....	1.08	1.40	1.12	.....
Ult. Oxygen	.....	.....	.....	.....	.....	21.15	21.92	22.64	.....
Calorific value determined:									
Calories	.....	.....	.....	.....	.....	6,231	6,534	6,654	.....
British thermal units	.....	.....	.....	.....	.....	11,214	11,762	11,977	.....
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	7 2	7+	10+	10+	9+	26 10	8+	14+	18±
Thickness of part sampled	6 2	6–	6	5 2	5	8	6 4	7 6	7

	Coal Creek.	Coal Creek, probably "Old Government bank."[a]	Meeker.					Meeker, Curtis Creek.	Spring Creek, Nine-mile Hill.
Laboratory No.	3791.		3845.	3848.	3850.	3847.	3849.	3851.	3846.
Analysis of sample as received:									
Prox. Moisture	13.60	.....	11.90	11.22	13.39	12.03	12.55	8.88	24.87
Prox. Volatile matter	36.17	.....	33.14	33.43	33.76	34.21	34.64	33.51	32.30
Prox. Fixed carbon	45.57	.....	48.30	48.78	47.67	47.43	48.63	48.12	38.92
Prox. Ash	4.66	.....	6.66	6.57	5.18	6.33	4.18	9.49	3.91
Ult. Sulphur	.45	.....	.47	.57	.52	.51	.47	.67	.49
Ult. Hydrogen	5.71	.....	5.72	.....	.....	5.72	.....	.....	.....
Ult. Carbon	61.92	.....	63.89	.....	.....	64.31	.....	.....	.....
Ult. Nitrogen	1.32	.....	1.33	.....	.....	1.30	.....	.....	.....
Ult. Oxygen	25.94	.....	21.93	.....	.....	21.83	.....	.....	.....
Calorific value determined:									
Calories	6,073	.....	6,298	.....	.....	6,384	.....	.....	.....
British thermal units	10,931	.....	11,336	.....	.....	11,491	.....	.....	.....
Loss of moisture on air drying	4.10	.....	3.70	6.10	4.20	3.60	3.70	2.50	15.10

[a] Republished from Hills, R. C., Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 364.

Analyses of coal samples from Danforth Hills and Grand Hogback coal fields, in northwestern Colorado—Continued.

	Coal Creek.	Coal Creek, probably "Old Government bank."[a]	Meeker.					Meeker, Curtis Creek.	Spring Creek, Ninemile Hill.
Laboratory No.	3791.		3845.	3848.	3850.	3847.	3849.	3851.	3846.
Analysis of air-dried sample:									
Prox. Moisture	9.90	7.63	8.51	5.45	9.59	8.74	9.19	6.54	11.51
Prox. Volatile matter	37.72	36.61	34.41	35.60	35.24	35.49	35.97	34.37	38.05
Prox. Fixed carbon	47.52	53.11	50.16	51.95	49.76	49.20	50.50	49.35	45.88
Prox. Ash	4.86	2.65	6.92	7.00	5.41	6.57	4.34	9.74	4.64
Ult. Sulphur	.47	.48	.49	.61	.54	.53	.49	.69	.50
Ult. Hydrogen	5.47	.....	5.51	.....	.....	5.52	.....	.....	.....
Ult. Carbon	64.57	.....	66.34	.....	.....	66.71	.....	.....	.....
Ult. Nitrogen	1.38	.....	1.38	.....	.....	1.35	.....	.....	.....
Ult. Oxygen	23.25	.....	19.36	.....	.....	19.32	.....	.....	.....
Calorific value determined:									
Calories	6,333	.....	6,540	.....	.....	6,622	.....	.....	.....
British thermal units	11,397	11,010	11,772	.....	.....	11,920	.....	.....	.....
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	25+	.....	7	7	7 8	[a] 20±	7±	5+	5±
Thickness of part sampled	8 9	.....	5 8	5 1	3 9	7 3	5 3	4 10	4 6

	Rifle Creek.		Harvey or Dry Gap, 14-foot bed.[b]	Harvey or Dry Gap, Wheeler bed.[b]	Newcastle.				
Laboratory No.	3943.	3946.			3936.	3932.	3938.	3933.	3937.
Analysis of sample as received:									
Prox. Moisture	6.32	7.21	.....	.....	3.68	4.16	3.51	3.51	4.00
Prox. Volatile matter	36.90	36.09	.....	.....	36.66	35.55	38.38	38.50	38.41
Prox. Fixed carbon	50.84	51.39	.....	.....	52.77	54.94	53.17	53.34	53.74
Prox. Ash	5.94	5.31	.....	.....	6.89	5.35	4.94	4.65	3.85
Ult. Sulphur	1.12	.69	.....	.....	.44	.42	.54	.52	.51
Ult. Hydrogen	5.48	5.50	.....	.....	5.12	5.27	5.10	.....	.....
Ult. Carbon	68.72	68.21	.....	.....	71.99	73.24	72.86	.....	.....
Ult. Nitrogen	1.57	1.58	.....	.....	1.39	1.44	1.74	.....	.....
Ult. Oxygen	17.17	18.71	.....	.....	14.17	14.28	14.82	.....	.....
Calorific value determined:									
Calories	6,903	6,856	.....	.....	7,178	7,290	7,370	.....	.....
British thermal units	12,425	12,341	.....	.....	12,920	13,122	13,266	.....	.....
Loss of moisture on air drying	2.10	3.10	.....	.....	.90	1.00	.80	.70	1.20
Analysis of air-dried sample:									
Prox. Moisture	4.31	4.24	4.54	4.81	2.81	3.19	2.73	2.83	2.83
Prox. Volatile matter	37.69	37.24	40.67	36.45	36.99	35.91	38.69	38.77	38.88
Prox. Fixed carbon	51.93	53.04	51.09	45.79	53.25	55.49	53.60	53.72	54.39
Prox. Ash	6.07	5.48	3.70	2.95	6.95	5.41	4.98	4.68	3.90
Ult. Sulphur	1.14	.71	.55	.53	.44	.42	.54	.52	.52
Ult. Hydrogen	5.36	5.32	.....	.....	5.07	5.21	5.05	.....	.....
Ult. Carbon	70.20	70.39	.....	.....	72.65	73.98	73.45	.....	.....
Ult. Nitrogen	1.60	1.63	.....	.....	1.40	1.45	1.76	.....	.....
Ult. Oxygen	15.63	16.47	.....	.....	13.49	13.53	14.22	.....	.....
Calorific value determined:									
Calories	7,072	7,075	.....	.....	7,243	7,364	7,429	.....	.....
British thermal units	12,691	12,736	12,933	11,412	13,037	13,255	13,373	.....	.....
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	7 3	7 3	.....	.....	2—	2—	14	14	14
Thickness of part sampled	7 3	5 9	.....	.....	1 8	1 8	9	4 2	5 3

[a] Thickness reported; not verified.
[b] Republished from Hills, R. C., Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 364.

Analyses of coal samples from Danforth Hills and Grand Hogback coal fields, in northwestern Colorado—Continued.

	Newcastle.		South Canyon, east Wheeler bed.		South Canyon, D bed.	Gulch, Sunshine bed.	Gulch, Anderson bed.	Coal Basin.	
Laboratory No.	3935.	3939.	3959.	3960.	3961.	4010.	4009.	4041.	4043.
Analysis of sample as received:									
Prox. Moisture	4.04	4.06	6.55	5.51	7.44	2.30	2.77	1.33	1.15
Prox. Volatile matter	37.66	38.20	36.63	35.89	36.18	34.74	35.15	21.48	22.43
Prox. Fixed carbon	52.56	52.71	47.89	48.76	53.90	56.71	58.68	70.24	68.85
Prox. Ash	5.74	5.03	8.93	9.84	2.48	6.25	3.40	6.95	7.57
Ult. Sulphur	.53	.51	.48	.29	.47	.44	.46	.51	.48
Ult. Hydrogen	.....	5.24	.....	5.27	5.36	5.23	.....	.....	.....
Ult. Carbon	.....	72.98	.....	65.66	69.73	76.12	.....	.....	.....
Ult. Nitrogen	.....	1.71	.....	1.36	1.65	1.54	.....	.....	.....
Ult. Oxygen	.....	14.53	.....	17.58	20.31	10.42	.....	.....	.....
Calorific value determined:									
Calories	.....	7,352	.....	6,606	7,047	7,766	.....	.....	.....
British thermal units	.....	13,234	.....	11,891	12,685	13,979	.....	.....	.....
Loss of moisture on air drying	1.10	1.20	2.20	1.70	3.10	1.20	1.50	.40	.30
Analysis of air-dried sample:									
Prox. Moisture	2.97	2.90	4.45	3.88	4.48	1.21	1.29	.93	.85
Prox. Volatile matter	38.08	38.66	37.45	36.51	37.34	35.17	35.69	21.57	22.50
Prox. Fixed carbon	53.14	53.35	48.97	49.60	55.62	57.30	59.57	70.52	69.06
Prox. Ash	5.81	5.09	9.13	10.01	2.56	6.32	3.45	6.98	7.59
Ult. Sulphur	.54	.52	.49	.30	.49	.45	.47	.51	.48
Ult. Hydrogen	.....	5.17	.....	5.17	5.18	5.16	.....	.....	.....
Ult. Carbon	.....	73.87	.....	66.79	71.96	77.05	.....	.....	.....
Ult. Nitrogen	.....	1.73	.....	1.38	1.70	1.56	.....	.....	.....
Ult. Oxygen	.....	13.62	.....	16.35	18.11	9.46	.....	.....	.....
Calorific value determined:									
Calories	.....	7,441	.....	6,720	7,376	7,860	.....	.....	.....
British thermal units	.....	13,394	.....	12,106	13,090	14,149	.....	.....	.....
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	14	14	18+	.....	4 8	14±	4 10	[a] 20	[a] 20
Thickness of part sampled	9	14	12 8	15 10	4 8	.....	4 10	6 3	7 6

	Coal Basin.			Sunlight, C bed.	Sunlight, B bed.	Sunlight, D bed.		Sunlight, A bed.	
Laboratory No.	4047.	4049.	4042.	4045.	4046.	4033.	4048.	4032.	4034.
Analysis of sample as received:									
Prox. Moisture	0.96	1.22	1.27	5.65	6.93	5.19	6.49	5.50	5.32
Prox. Volatile matter	21.49	22.02	22.38	36.29	35.55	47.77	37.23	24.68	36.29
Prox. Fixed carbon	68.93	67.84	67.35	52.89	52.73	43.21	53.38	58.64	49.60
Prox. Ash	8.62	8.92	9.00	5.17	4.79	3.83	2.90	11.18	8.79
Ult. Sulphur	.52	.59	.50	.82	.67	.79	.93	.69	.76
Ult. Hydrogen	4.66	.....	.....	.....	.....	.....	5.56	.....	5.26
Ult. Carbon	79.61	.....	.....	.....	.....	.....	71.51	.....	67.76
Ult. Nitrogen	1.83	.....	.....	.....	.....	.....	1.79	.....	1.58
Ult. Oxygen	4.76	.....	.....	.....	.....	.....	17.31	.....	15.85
Calorific value determined:									
Calories	7,961	.....	.....	.....	.....	.....	7,299	.....	6,902
British thermal units	14,330	.....	.....	.....	.....	.....	13,138	.....	12,424
Loss of moisture on air drying	.20	.40	.40	2.60	3.80	2.00	3.50	2.80	3.00
Analysis of air-dried sample:									
Prox. Moisture	.76	.82	.87	3.13	3.25	3.26	3.10	2.78	2.39
Prox. Volatile matter	21.53	22.11	22.47	37.26	36.96	48.74	38.58	25.39	37.41
Prox. Fixed carbon	69.07	68.11	67.62	54.30	54.81	44.09	55.32	60.33	51.14
Prox. Ash	8.64	8.96	9.04	5.31	4.98	3.91	3.00	11.50	9.06
Ult. Sulphur	.52	.59	.50	.84	.69	.81	.96	.71	.78
Ult. Hydrogen	4.65	.....	.....	.....	.....	.....	5.36	.....	5.08
Ult. Carbon	79.77	.....	.....	.....	.....	.....	74.10	.....	69.86
Ult. Nitrogen	1.83	.....	.....	.....	.....	.....	1.86	.....	1.63
Ult. Oxygen	4.59	.....	.....	.....	.....	.....	14.72	.....	13.59
Calorific value determined:									
Calories	7,977	.....	.....	.....	.....	.....	7,564	.....	7,115
British thermal units	14,359	.....	.....	.....	.....	.....	13,614	.....	12,808
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	20	[a] 20	.....	.....	.....	9±	8 3	10−	10 9
Thickness of part sampled	9	9	.....	.....	6	4	8 3	7 6	10 2

[a] Thickness reported; not verified.

Analyses of coal samples from Danforth Hills and Grand Hogback coal fields, in northwestern Colorado—Continued.

	1 mile north of Sunlight.				8 miles southwest of Glenwood Springs.				
Laboratory No.	4035.	4031.	4036.	4039.	4040.	4037.	4038.	4030.	4050.
Analysis of sample as received:									
Prox. Moisture	6.06	6.36	6.10	5.90	10.07	12.10	10.73	13.10	14.11
Prox. Volatile matter	36.13	38.18	38.47	38.24	31.82	34.50	33.09	33.41	32.71
Prox. Fixed carbon	47.78	51.92	53.53	52.67	43.47	48.46	44.50	46.46	43.99
Prox. Ash	10.03	3.54	1.90	3.19	14.64	4.94	11.68	7.03	9.19
Ult. Sulphur	.77	.80	.52	.58	.76	.85	.78	1.13	.91
Ult. Hydrogen	.....	.....	5.60	.....	.....	.....	.....	.....	5.50
Ult. Carbon	.....	.....	72.18	.....	.....	.....	.....	.....	57.97
Ult. Nitrogen	.....	.....	1.74	.....	.....	.....	.....	.....	1.46
Ult. Oxygen	.....	.....	18.06	.....	.....	.....	.....	.....	24.97
Calorific value determined:									
Calories	.....	.....	7,316	.....	.....	.....	.....	.....	5,753
British thermal units	.....	.....	13,169	.....	.....	.....	.....	.....	10,355
Loss of moisture on air drying	3.00	2.90	2.00	2.40	5.60	4.30	5.90	7.20	7.60
Analysis of air-dried sample:									
Prox. Moisture	3.15	3.56	4.18	3.57	4.73	8.15	5.13	6.36	7.05
Prox. Volatile matter	37.25	39.32	39.25	39.18	33.71	36.05	35.17	36.00	35.40
Prox. Fixed carbon	49.26	53.47	54.63	53.97	46.05	50.64	47.29	50.06	47.60
Prox. Ash	10.34	3.65	1.94	3.28	15.51	5.16	12.41	7.58	9.95
Ult. Sulphur	.79	.82	.33	.59	.80	.89	.83	1.22	.98
Ult. Hydrogen	.....	.....	5.49	.....	.....	.....	.....	.....	5.04
Ult. Carbon	.....	.....	73.65	.....	.....	.....	.....	.....	62.74
Ult. Nitrogen	.....	.....	1.78	.....	.....	.....	.....	.....	1.58
Ult. Oxygen	.....	.....	16.61	.....	.....	.....	.....	.....	19.71
Calorific value determined:									
Calories	.....	.....	7,465	.....	.....	.....	.....	.....	6,226
British thermal units	.....	.....	13,437	.....	.....	.....	.....	.....	11,206
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	6 2	7 6	9 11	9 11	9 3	8	16±	5±	.....
Thickness of part sampled	6 2	7 6	9 3	7 6	9 3	8	16±	4 1	5 1

THE BOOK CLIFFS COAL FIELD, BETWEEN GRAND RIVER, COLORADO, AND SUNNYSIDE, UTAH.

By G. B. RICHARDSON.

INTRODUCTION.

The Book Cliffs coal field is part of the southern edge of an immense basin in western Colorado and eastern Utah around which the outcrop of coal-bearing rocks can be traced for more than 500 miles. Pl. XVIII shows the outline of this field. On the southwest from the vicinity of Mount Hilgard, Utah, northward to Castlegate, the coal measures form the eastern escarpment of the Wasatch Plateau. Thence they trend southeastward to Grand River, constituting in the Book Cliffs the southern rim of the Uinta Basin. Beyond Grand River the coal measures continue eastward, forming the southern base of Grand Mesa and extending to the vicinity of Crested Butte. From that place the outcrop trends northward and, crossing Grand River again in the vicinity of Newcastle, continues northward along the Grand Hogback to the Danforth Hills. Thence the coal measures turn westward and outcrop along the southern flank of the Uinta Mountains. This great coal field has been but partially prospected and mines are in operation in only a few localities, but enough of the area has been explored to prove that it is one of the most important coal reserves of the Rocky Mountain region.

Coal has long been known to be present in the Book Cliffs. The geology of the region was first studied by A. C. Peale,[a] of the Hayden Survey, in 1876. The field is mentioned by R. C. Hills[b] in his report on the "Coal fields of Colorado," and by L. S. Storrs[c] in his paper on the "Rocky Mountain coal fields." Arthur Lakes has also referred to part of the area[d] and has described the Book Cliff mines.[e] But the coal was not examined in detail until 1905, when J. A. Taff,[f] of the United States Geological Survey, studied the western part of

[a] Geological report on the Grand River district: Tenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1878, pp. 170-185.

[b] Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 353.

[c] Twenty-second Ann. Rept. U. S. Geol. Survey, p. 3, 1901, p. 436.

[d] The Grand River coal field: Mining Reports, vol. 51, 1905, pp. 379-381.

[e] The Book Cliff coal mines: Mines and Minerals, vol. 24, 1904, pp. 289-291.

[f] The Book Cliffs coal field: Bull. U. S. Geol. Survey No. 285, 1906, pp. 289-302.

the field from the vicinity of Sunnyside to Castlegate, Utah, and its southern continuation along the escarpment of the Wasatch Plateau. During the summer of 1906 the writer, assisted by W. D. Neal, L. J. Pepperberg, and C. D. Perrin, made a reconnaissance survey of the eastern part of the Book Cliffs field, from the point where Mr. Taff's work terminated to Grand River, Colorado. The following pages are an abstract of a more detailed report, which will soon be published.

TOPOGRAPHY.

The Book Cliffs form the southern margin of the Book or Tavaputs Plateau, which is separated from the San Rafael Swell and the Uncompahgre Plateau on the south by a broad lowland. The elevations range from 4,000 to 10,000 feet above sea level. The area is drained by Green and Grand rivers, which unite to form the Colorado about 60 miles south of the Book Cliffs.

The lowland at the base of the Book Cliffs extends in a curved but general westerly direction from Palisades, Colo., to Green River, Utah, and thence northwestward to Helper, a distance of 190 miles. In the area here considered this belt of lowland, averaging about 12 miles in width, lies between the Book Cliffs on the north and low hills on the south. It is an undulating desert plain that rises gently toward the bordering highlands. In the vicinity of the cliffs there are outlying buttes, and the shale is eroded into badlands. Adjoining the cliffs there are local fringing remnants of an old outwash gravel-covered plain through which the streams have cut their way 100 feet or more, and south of Grand River, near Palisades, a system of terraces is well developed.

The Book Cliffs extend from Grand River, Colorado, to Helper, Utah, at the east edge of the Wasatch Plateau. They occupy a belt from 1 to 10 miles wide in which the elevation rises from 2,000 to 6,000 feet. In places the rise is abrupt in one sharp precipitous slope, but usually it is accomplished by a series of cliffs and intervening benches. The rocks composing the escarpments are alternating beds of sandstone and shale lying almost flat, and the strata present the appearance of the leaves of a book when lying on one side; hence the name.

In the area here discussed the cliffs extend in an S-shaped belt from Palisades to Sunnyside. At the east they are much dissected by Roan Creek and its tributaries, and a subordinate escarpment known as the Little Book Cliffs extends northwestward from the mouth of the Grand River canyon. The top of the Little Book Cliffs marks the crest of a hogback whose northeastern flanks constitute a dip slope, and the area between the Little Book Cliffs and Roan Creek is a gentle northeastward-sloping monocline dissected by southeastward-flowing streams.

West of the headwaters of Roan Creek the Book Cliffs proper extend to the end of the area mapped. Erosion by East and West Salt Creek has caused the rim of the Book Plateau to recede so that the distance between the lowlands and the plateau, a few miles east of the Utah-Colorado boundary, is unusually large. Between the State line and Green River this distance averages about 10 miles. Here a low bench, that is not present elsewhere, forms the base of the cliffs. It is caused by a great lens of sandstone which is overlain by shale. Above this lowest bench there is a succession of dissected benches and escarpments up to the level of the plateau.

Green River has produced another embayment in the cliffs, and Price River in its canyon course separates a small area, known as the Beckwith Plateau, from the main mass of the upland. The Beckwith Plateau is considerably dissected on the north and east, but faces the lowland on the west in a practically unbroken scarp over 1,500 feet high. Northwest of the Beckwith Plateau to the end of the area studied, a line of cliffs, which form the base of an eastward-sloping shelf, rises 1,000 to 1,500 feet directly above the lowland. Above this shelf another but more dissected line of cliffs rises 1,500 feet higher.

The crest of the Book Cliffs forms the southern rim of the Book Plateau, or, as it is known in Utah, the Tavaputs Plateau, which, viewed from the south, exhibits an even sky line. This plateau slopes gently northward toward the axis of the Uinta Basin, but is much dissected by deep canyons.

STRATIGRAPHY.

In the Book Cliffs coal field, the rocks are all sedimentary and are divisible into four distinct lithologic groups which range in age from Dakota to Eocene.

The Dakota possesses the characteristic features common to the formation in this general region. It is a variable series of buff quartzitic sandstone, commonly conglomeratic, with a few layers of carbonaceous shale and low-grade coal. Generally it ranges in thickness from 25 to 200 feet, but in places it is wanting, evidently having been deposited unconformably upon an old land surface. The outcrop occupies a narrow belt of low hills parallel to and about 10 miles south of the Book Cliffs.

Above the Dakota there are several thousand feet of clay shale, which underlies the broad central lowland and forms the base of the Book Cliffs. The shale is black or blue-gray to drab in color, and contains local lenses of limestone and at the top thin beds of buff sandstone. It is much broken by cracks and joints, many of which contain thin films of alkaline salts that locally effloresce in patches of white powder. The unreclaimed areas of shale are characteristically *coated* with "alkali." The shale is about 3,000 feet thick. It con-

tains Colorado fossils at the base and Montana fossils near the top and is correlated with the Mancos shale of southwestern Colorado.

Well-exposed sections in the face of the cliffs show that the shale grades upward into the overlying formation with no apparent break in sedimentation and a sharp boundary can not be drawn between them. The overlying rocks consist of alternating beds of buff sandstone and drab or carbonaceous shale with workable beds of coal in the lower part. These are the escarpment-making rocks of the Book Cliffs and are clearly exposed throughout the area. About a third of the formation is composed of shale, most of which occurs in the lower half, while the upper part consists largely of sandstone. The areal distribution of the different strata is varied and no two sections are exactly alike. Some beds of sandstone, however, are persistent for several miles. The thickness of the formation decreases toward the west and ranges from about 2,200 to 1,200 feet. Fossils have been found at several horizons between 200 feet from the base and 250 feet from the top of the formation. They consist of land plants and fresh- and brackish-water invertebrates. The evidence of the fossils and the general stratigraphic and oval relation of the beds together indicate that the coal-bearing formation should be referred to the Mesaverde rather than to the Laramie. The transition from the Mancos to the Mesaverde is marked lithologically by the increasing prevalence of sand and paleontologically by the change from marine to brackish- and fresh-water conditions. On lithologic grounds all the coal beds would be classed with the sandstone-shale formation, the greater part of which at least is considered to be Mesaverde.

Strata of Eocene age cap the Book Cliffs and for many thousand square miles constitute the floor of the Uinta Basin to the north. The basal Eocene beds are composed of local conglomerate, varicolored shale, buff sandstone, and subordinate thin lenses of limestone in which fossils, referred to the Wasatch stage, have been found. The stratigraphy is characteristically varied and many adjacent sections are very unlike; in one place the varicolored shales predominate and in another they are inconspicuous. The conglomerate is also variable in occurrence. In some sections none was seen, whereas others show about 25 feet of it. It is composed of rounded pebbles of quartz, quartzite, and chert, colored red, pink, black, and white, in a sandy matrix. No structural discordance was found between the two formations, but locally the conglomerate lies upon an undulatory surface of the underlying rocks. Other evidences of unconformity at the base of the Eocene are the westward thinning of the Mesaverde and the difference in general character between the two formations, representing the change from brackish- and fresh-water sediments to those laid down under more diverse conditions of deposition, probably in part subaerial and in part lacustrine.

COAL.

Coal of commercial importance occurs in the Book Cliffs in the lower part of the sandstone-shale formation at intervals between 35 and 700 feet above the shale that underlies the lowland. It occurs at different horizons, and no bed has been traced continuously for more than a few miles. In one locality several beds of coal are present, while in others only one or two have been found. The thickness ranges from 21 feet down to mere films of carbonaceous matter. The section on Pl. XVIII indicates the general sequence of the rocks.

OCCURRENCE AND THICKNESS.

The following description begins at the east and proceeds westward, and in following it the map (Pl. XVIII) will be of service:

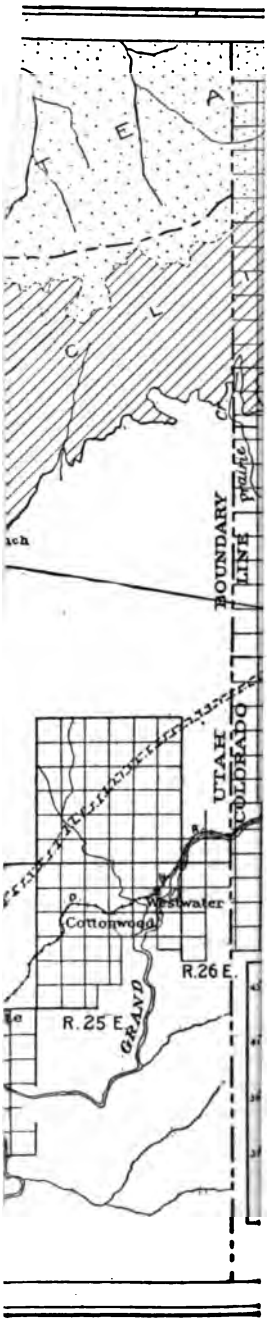
At the east end of the Book Cliffs there are two workable beds of coal. The lower one occurs between 35 and 60 feet above the top of the shale that underlies the lowland and, though variable, is commonly about 4 feet thick. The upper coal is thicker, in places measuring 9 feet, and occurs from 200 to 500 feet above the lower beds. These coals have been prospected at several localities between the Cameo mine (No. 1 on the map) and the Farmer's mine (No. 13), and, though they have not been actually traced throughout that distance and are known to vary in thickness, the beds appear to be continuous. Besides these two main coals there are usually one or more thin beds, but no others of commercial importance have yet been found.

The lower coal, also known as the Palisades coal, outcrops at water level near the mouth of the Hogback Canyon of Grand River about 1½ miles above Palisades. Thence the coal can be traced westward along the base of the Book Cliffs for many miles. At first it rises rapidly above the valley. At the Palisades mine (No. 6 on the map) the coal is about 150 feet above the valley, at the Garfield mine (No. 7) it is 800 feet, and at the old Book Cliff mine (No. 9) the Palisades coal is about 1,200 feet above the river. In this distance the coal can be easily followed; at many places it is exposed by erosion, appearing as a black streak in the cliffs, and it is usually underlain by a massive white sandstone which is conspicuous as the first heavy sandstone bed above the shale. This sandstone is not persistent, however, but locally thickens and thins and gives way to shaly beds. The Palisades coal varies in thickness, ranging from a few inches to 6 feet.

At the Riverside mine (No. 4), a mile northeast of Palisades, the following section is exposed near the mouth of the mine:

Section of coal bed at Riverside mine.

	Ft.	in.
Shale.		
Coal		6
Shale		3
Coal	2	6
	3	3



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At the face of the workings the shale parting is an inch and a half thick, and the lower bench of coal measures 2 feet 10 inches.

At the Palisades mine (No. 6) there are from 3 feet 7 inches to 3 feet 10 inches of clean coal. Two miles farther west, at the Garfield mine, the Palisades coal attains the greatest thickness yet measured. The following section is there exposed:

Section of coal bed at Garfield mine.

	Ft.	in.
Sandstone, shaly.		
Coal	1	1
Bone		2
Coal	1	9
Bone		¼
Coal	3	2
Bone		
Coal	1	
Shale, carbonaceous	1	
Sandstone.		
Total coal bed	7	11¼

In the vicinity of the old Book Cliff mine the lower coal is of variable thickness; in places it measures almost 5 feet, whereas near by it thins out to almost nothing. It is reported that in working the lower coal in the old Book Cliff mine several barren areas were encountered in which the coal was absent. Northwest of the old mine evidences of thinning are shown by the outcrops.

West of the Book Cliff mine less prospecting has been done, and little variation has been found. At the Steele or Keystone mine (No. 11) there are 5 feet 3 inches of coal, including 4 inches of bone 1 foot from the top. The roof and floor are of shale, and the coal lies 3 feet above a bed of massive white sandstone.

At the Black Diamond mine (No. 12) the following section was measured:

Section of coal bed at Black Diamond mine.

	Ft.	in.
Shale.		
Coal		9–11
Clay		1– 3
Coal	4	8
Shale.		
	5	6

Locally the coal decreases in thickness to 3 feet. At the Farmer's mine the lower coal seems to have decreased to 30 inches, but in this vicinity the upper coal is of more value.

Except at two important mines, the Book Cliff (No. 10) and the Cameo (No. 1), the upper coal is not worked. This is due to the fact that the lower coal in general is of better quality and more accessible, occurring several hundred feet lower down the steep cliffs.

The upper bed, which is known as the Cameo coal, outcrops at river level at Cameo station. It rises to the southwest, and north of Palisades is about 650 feet above the valley, lying at the base of the second tier of cliffs. From Palisades the outcrop extends northwestward to the vicinity of the Book Cliff mine, at a distance of about 1½ miles from the crest of the lower escarpment. Thence westward the bench below the upper coal disappears, and the two coals outcrop in the face of the cliffs almost directly one above the other. The position of the upper coal is marked locally by a massive white sandstone almost immediately beneath it. This sandstone is 75 feet thick and can be traced for miles, but it is not constant and in places disappears.

Between the Cameo and Bob Cat mines the thickness of the upper coal as exposed in mines or prospects ranges between 4 feet 4 inches and 9 feet 8 inches, with one or two partings of shale or bony coal ranging from 5 inches to 3 feet 5 inches.

In the Cameo mine the roof is a good, firm sandy shale, and the floor where the full thickness of coal is worked is reported to be sandstone, but usually the total thickness of the coal is not removed. The coal here has the reputation of being dirty. The following measurements were made in the main entry of the mine:

Section of coal bed in the Cameo mine.

	Ft.	in.
Coal	3	10
Bone		1
Coal	3	10
Bone	1	2
Coal	2	
	10	11

At a prospect north of Palisades the following section is exposed:

Section of coal at prospect north of Palisades.

	Ft.	in.
Coal	3	6
Bone		1
Coal	2	5
	6	

At the Book Cliff mine (No. 10) about 7 feet of the upper coal are worked, and at the end of the main entry the following section was measured:

Section of coal bed in Book Cliff mine.

	Ft.	in.
Coal	3	
Bone		¼
Coal	4	6
	7	6¼

About a quarter of a mile east of the Steele mine (No. 11) a stripping was made which showed:

Section of coal bed one-fourth mile east of Steele mine.

	Ft.	in.
Coal	2	6
Bone		5
Coal	3	2
Shale		8
Sandstone.		
Total coal bed	6	1

At the Bob Cat mine (No. 14) and in that vicinity between 44 and 55 inches of clear coal are exposed at the upper coal horizon, which occurs about 400 feet above the lower bed worked at the Farmer's mine. West of the Bob Cat mine the upper coal has not been prospected, and little is known of it for several miles. The coal outcrops high in the face of the cliffs, and the lower bed is more accessible.

Two small openings on the lower coal west of the Farmer's prospect are known as the Excelsior and Corcoran mines. The Excelsior mine (No. 15) is located high up a hillside near the head of a small gulch, where the coal is opened along the outcrop at several places. At the entrance to the workings 4 feet 7 inches of coal is exposed. Four feet above is a 4-inch bed and a foot and a half below there are 2 inches of coal, while 40 feet below the main coal there is an unprospected bed of coal and carbonaceous shale 6 feet thick. A mile west of the Excelsior there is a small abandoned prospect known as the Corcoran mine (No. 16) where the workings have caved in, but there are at least 4 feet of coal exposed near the entrance.

For 5 miles northwest of the Corcoran property little or no prospecting has been done, but at the next open valley there are prospects on both the upper and lower coals. An opening on the lower bed shows the following section:

Section of coal bed 5 miles northwest of Corcoran mine.

	Ft.	in.
Sandstone.		
Shale		6
Coal	3	
Bone		4
Coal	2	
Shale		4
Sandstone.		
Total coal bed	5	10

Farther up the same valley the upper coal is well exposed and has been worked at the Hunter mine (No. 17), where the following section was measured:

Section of coal beds at Hunter mine.

	Ft.	in.
Sandstone.		
Coal	2	
Bone		4
Coal	4	5
Bone		8
Coal		7
Sandstone	25	
Coal	2	
Bone	1	
Coal	3	
Sandstone.		
	39	

Northwestward along the cliffs no prospects were found for 5 miles northwest of the Hunter property, where the Gross or Kiel mine is situated, near the mouth of Kiel Canyon. At this mine (No. 18) between 3 feet and 3 feet 9 inches of coal are exposed.

The next opening is about 1½ miles west of Kiel Canyon at the Nugent mine (No. 19). Here there are two openings on the lower coal on opposite sides of a gulch. The coal is from 4 feet 3 inches to 4 feet 8 inches thick.

At the Nearing mine (No. 20), three-fourths of a mile west of the Nugent, the same bed is worked. At the mouth of the mine the coal measures 4 feet to 4 feet 2 inches and contains a variable streak of bone up to 12 inches thick. At the end of the workings the bone disappears and the coal measures 4 feet 7 inches. The coal is here 45 feet above the top of the shale, and in this general vicinity the higher coal appears to be represented by only thin carbonaceous layers. Only one workable coal has yet been found here.

Openings have been made on the coal at the Lane and Johnson mines, on opposite sides of the creek about 2 miles northwest of the Nearing property. The following measurements were made:

Section of coal bed at Johnson mine (No. 22).

	Ft.	in.
Sandstone.		
Shale, carbonaceous		5
Coal	1	6
Bone		3
Coal	4	
Total coal bed	5	9

Section of coal bed at Lane mine (No. 23).

	Ft.	in.
Sandstone.		
Shale, sandy		4
Coal	1	3
Bone		4
Coal	3	
Shale, carbonaceous	1	
Coal, bony	1	
Shale.		
	6	11

A mile and a half up the creek are outcrops of several coal beds which have not been prospected. These have the following section:

Section of higher coal beds 1½ miles east of Lane mine.

	Ft.	in.
Shale.		
Coal	1	4
Bone and coal		8
Coal	1	3
Shale, carbonaceous	2	
Coal	3	10
Shale, carbonaceous	18	
Coal		8
Shale, carbonaceous	7	
Coal	4	1
Shale.		
	38	10

The following section was measured at about the same horizon on the cliffs north of Malone's ranch:

Section of high coal beds 3 miles north of Malone's ranch.

	Ft.	in.
Shale, carbonaceous.		
Coal	1	4
Bone		6
Coal	2	
Bone		5
Coal		5
Bone		4
Coal	3	10
Shale, sandy	7	
Coal	3	1
	18	11

The higher coal here is in two benches, as at the Hunter mine, and appears to be well developed, but it has not been prospected. Little is known of the coal between the Lane and Johnson mines and the vicinity of Carbonera, near the Colorado-Utah boundary. Though undeveloped, coal has been found wherever sections have been measured.

About 2½ miles above the entrance to the canyon of East Salt Creek, along a small tributary about half a mile east of its mouth, a bed of coal with the unusual thickness of 21 feet 5 inches is exposed by a waterfall. This is the greatest measurement of coal made in the entire area under consideration. No development and but little prospecting has been done here, and the lateral extent of this bed has not been determined. It thins out rapidly to the west, however, for in following the bed along the hillside above the gulch the coal was found to thin out and disappear.

In the vicinity of Carbonera some prospecting has been done, and a mine is being worked by the Uinta Railroad Company. Within a distance of 450 feet above the top of the shale there are four beds of coal more than 2 feet thick and several other thinner carbonaceous layers. At the Carbonera mine the coal measures almost 7 feet, but it is parted by two layers of bone, which greatly decreases the value.

In Utah, within the area covered by this report, there are no shipping mines and the coal has been prospected in only a few places. The Mesaverde formation, however, constitutes the cliff-making rocks and coal has been found wherever sections have been studied. In a distance of 60 miles, southwest from Carbonera to Thompsons, Utah, there are only three ranches, and these are situated near the mouths of canyons at the base of the Book Cliffs, where feeble streams of water flow throughout the summer. Near Bryson's ranch, on Westwater Creek, there are five beds of coal, ranging from 1 foot 3 inches to 2 feet 10 inches in thickness, in a section of 275 feet of rocks, the lowest coal occurring 95 feet above the top of the shale. From the Utah-Colorado boundary to some miles west of Thompsons, a bench 100 feet or more in height and half a mile to a mile in width, caused by a heavy bed of sandstone that is overlain by shale, extends along the base of the cliffs. Here the coal horizon, therefore, lies farther back in the cliffs than usual.

Near the Harms ranch (No. 28) is a bed of coal 1 foot 6 inches thick at the mouth of Cottonwood Canyon. Mr. Harms states that there are several beds in this vicinity ranging from 2 inches to 3 feet in thickness, but that the coal contains much bone and is of poor quality.

About 1½ miles above Nash's ranch (No. 29) are two beds of coal separated by an interval of 60 feet. The lower coal is 1 foot 10 inches thick and occurs 350 feet above the top of the shale; the higher coal measures 4 feet 8 inches, but little attempt has been made to develop it.

More work has been done on the coal north of Thompsons than anywhere else in Utah within the area covered by this report, but nevertheless the prospecting has not been thorough. Here there are five beds more than 2 feet thick in 125 feet of sandstone. The

principal work has been done at Ballard's mine (No. 30). At the mouth of this mine the following section was measured:

Section of coal bed at Ballard mine.

	Ft.	in.
Sandstone, shaly.		
Coal	1	3
Bone		2
Coal	1	10½
Bone		1½
Coal	2	3
Shale, carbonaceous.		
	5	8

At the face of the workings the coal bed consists of 5 feet 10½ inches of clean coal.

At a prospect on the west side of the gulch, opposite the Ballard mine, on a coal below the one there worked, the following section was measured:

Section of coal bed near Ballard mine.

	Ft.	in.
Sandstone, shaly.		
Coal		10
Bone		2
Sandstone		4
Coal	4	6
Shale.		
	5	10

The thickness of the partings is variable, even in near-by sections.

A thin bed of coal a few inches to a foot and a half in thickness occurs in the first massive sandstone above the top of the shale and shows up prominently from the valley as a black layer, but it is not thick enough to be of much importance.

Between Thompsons and Green River there is only one mine, the Black Baby, and almost no prospecting has been done. The few sections that were made did not reveal the presence of any beds more than 2 feet in thickness, but in the absence of prospecting little can be said of the coal in this part of the area. At the Black Baby mine (No. 33), about 10 miles northeast of the town of Green River, the following section was measured:

Section of coal bed at Black Baby mine.

	Ft.	in.
Shale, carbonaceous.		
Coal		3
Bone and shale		3
Coal	2	3
Bone		8
Coal	2	
Bone and shale	1	3
Coal	1	
	7	8

The lowest coal passes beneath water level at Green River, about 4 miles above the mouth of Price River, but no prospects were found in that vicinity.

West of Green River and south of Price River the coal occurs in an isolated area near the summit of the Beckwith Plateau, and north of Price River coal outcrops in the face of the cliffs high above the valley. At the northwest end of the Beckwith Plateau there are four beds of coal more than 2 feet thick and three others more than 1 foot, the lowest occurring about 340 feet above the top of the shale.

At Peterson's prospect (No. 34), high up on the hillside near the entrance to Price Canyon, the following section was measured:

Section at Peterson's prospect near Price Canyon.

	Ft.	In.
Shale, carbonaceous		8
Bone	1	2
Coal	4	
Shale, carbonaceous		10
Sandstone.		

About 225 feet above this, in a location that is difficult of approach, a bed 6 feet thick has been prospected.

Along the cliffs, between Price and Horse canyons, coal outcrops can be seen from the valley, but owing to their position high in the cliffs they have not been prospected. Two beds of coal, each 4 feet thick and lying about 200 feet apart, were measured about 10 miles north of Woodside.

At the west end of the area under consideration, in the vicinity of Horse Canyon, 6 miles south of Sunnyside, the coal has been considerably prospected. A large bed has been opened up and probably before long a mine will be located in Horse Canyon, although as yet there is no railroad connection and the property is 7 miles from the nearest point on the Denver and Rio Grande Railroad. The coal is between 250 and 300 feet above the top of the shale and is immediately underlain by a bed of massive white sandstone. Only one main bed of coal has been found in the vicinity of Horse Canyon, although at Sunnyside there are two beds.

In an entry on the west side of Horse Canyon (No. 37) the following section was measured:

Section of coal bed in Horse Canyon.

	Ft.	In.
Shale, carbonaceous		10
Coal	2	1
Bone		6
Sandstone and shale	1	6
Bone	1	
Coal	13	5
Sandstone.		
	19	4

A mile and a half farther south, at prospect No. 36, the section is as follows:

Section of coal bed at prospect No. 36.

	Ft.	in.
Sandstone, thin-bedded.		
Coal	2	4
Sandstone and shale	1	6
Coal	9	2
Bone		2
Coal	6	4
	19	6

AMOUNT OF AVAILABLE COAL.

A close estimate can not be made of the total amount of coal available, because of the present limited knowledge of this field. A rough approximation may be reached, however, by assuming that the practical limit of the field is 6 miles back from the outcrop and that the total thickness of coal may be represented by a single bed 7 feet thick extending throughout the area. The latter figure introduces an element of much uncertainty, inasmuch as the coals have not been continuously traced. On this basis there are in the area here considered about 1,010 square miles of coal land, 360 of which are in Colorado. A cubic foot of coal of 1.3 specific gravity weighs 81.25 pounds and a square mile of such coal 1 foot thick contains 1,132,544 short tons. Therefore on the above assumption the total amount is over 8,007,086,000 tons; deducting one-fourth for waste in mining leaves about 6,005,000,000 tons. These figures are perhaps of little more value than to express the fact that there is here an immense coal reserve.

COMPOSITION OF THE COAL.

The following analyses show the composition of coal from a number of localities in the area under discussion. The samples were collected under uniform conditions and represent the freshest available material. In general, however, because there are only a few working mines, most of the samples obtained were more or less affected by weathering. The specially poor ones are indicated in the list on p. 317. The samples were collected by cutting a channel across the face of the coal from roof to floor, partings over a quarter of an inch in thickness being rejected. The material was gathered on canvas, crushed, mixed, and quartered down to about 3 pounds and sent to the laboratory in a sealed can. The analyses were made by F. M. Stanton, chief chemist of the fuel-testing plant of the United States Geological Survey, under uniform conditions prescribed by N. W. Lord, in charge of chemical work.[a]

[a] Prof. Paper U. S. Geol. Survey No. 48, 1906, p. 174.

Proximate analyses of coals from the Book Cliffs coal field, Colorado-Utah.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Laboratory No.	3550.	3547.	3542	3540.	3546.	3541.	3549.	3539.	3545.
Analysis of sample as received:									
Moisture	8.42	8.17	7.55	4.71	7.57	7.52	8.77	9.02	13.96
Volatile matter	33.32	33.69	31.07	34.68	33.56	36.03	36.55	34.51	31.30
Fixed carbon	47.53	53.42	48.27	52.66	52.91	50.46	48.72	50.89	48.73
Ash	10.73	4.72	13.11	7.95	5.96	5.99	5.96	5.58	6.01
Sulphur	.60	.57	.57	.56	.72	.85	.83	.67	.63
Loss of moisture on air drying	4.30	2.80	2.60	.10	2.20	2.00	2.50	3.10	4.40
Analysis of air-dried sample:									
Moisture	4.30	5.52	5.08	4.61	5.49	5.63	6.43	6.11	10.00
Volatile matter	34.82	34.66	31.90	34.72	34.32	36.77	37.49	35.61	32.74
Fixed carbon	49.67	54.96	49.56	52.71	54.10	51.49	49.97	52.52	50.98
Ash	11.21	4.86	13.46	7.96	6.09	6.11	6.11	5.76	6.28
Fuel ratio	1.12	1.59	1.55	1.52	1.58	1.40	1.33	1.47	1.56

	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
Laboratory No.	3490.	3496.	3494.	3581.	3495.	3493.	3489.	3488.	3640.
Analysis of sample as received:									
Moisture	11.42	10.75	10.89	11.03	9.54	15.39	6.86	6.52	5.40
Volatile matter	34.25	34.83	34.12	35.90	34.49	32.57	34.20	35.75	33.30
Fixed carbon	44.49	47.58	44.77	46.35	46.33	45.69	43.90	48.37	55.57
Ash	9.84	6.84	10.22	6.72	9.64	6.35	15.04	9.36	5.73
Sulphur	.84	.55	1.09	.68	.78	.62	.62	.67	.49
Loss of moisture on air drying	5.60	3.50	5.20	5.80	3.10	7.20	1.80	.60	.20
Analysis of air-dried sample:									
Moisture	6.17	7.51	6.00	5.55	6.65	8.83	5.15	5.96	5.21
Volatile matter	36.28	36.09	35.99	38.11	35.59	35.10	34.83	35.96	33.36
Fixed carbon	47.13	49.31	47.23	49.21	47.81	49.23	44.70	48.66	55.69
Ash	10.42	7.09	10.78	7.13	9.95	6.84	15.32	9.42	5.74
Fuel ratio	1.30	1.32	1.31	1.29	1.34	1.40	1.28	1.35	1.67

	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.
Laboratory No.	3587.	3585.	3586.	3584.	3730.	3728.	3729.	3732.	3734.
Analysis of sample as received:									
Moisture	9.44	9.73	8.27	5.55	18.63	9.32	10.96	10.77	11.23
Volatile matter	35.51	35.27	36.00	36.01	30.61	33.64	32.19	33.68	31.51
Fixed carbon	49.33	49.95	48.67	52.75	46.28	49.52	42.45	48.36	45.31
Ash	5.72	5.05	6.16	5.69	4.48	7.52	14.40	7.19	11.95
Sulphur	1.02	1.30	1.26	.93	.38	.51	.48	.56	.42
Loss of moisture on air drying	5.50	5.20	3.60	1.60	9.10	3.00	4.50	3.90	4.70
Analysis of air-dried sample:									
Moisture	4.17	4.78	4.84	4.01	10.48	6.52	6.76	7.15	6.85
Volatile matter	37.58	37.20	38.28	36.60	33.68	34.68	33.71	35.05	33.07
Fixed carbon	52.20	52.69	50.49	53.61	50.91	51.05	44.45	50.32	47.54
Ash	6.05	5.33	6.39	5.78	4.93	7.75	15.08	7.48	12.54
Fuel ratio	1.39	1.41	1.32	1.46	1.51	1.47	1.32	1.44	1.44

	XXVIII.	XXIX.	XXX.	XXXI.	XXXII.	XXXIII.	XXXIV.	XXXV.
Laboratory No.	3854.	3856.	3857.	3945.	3957.	4014.	4013.	4015.
Analysis of sample as received								
Moisture	12.74	6.35	9.57	5.58	4.75	9.79	9.01	5.20
Volatile matter	33.04	31.89	32.37	32.77	33.58	33.39	31.78	36.03
Fixed carbon	50.06	42.74	47.09	43.61	50.24	50.44	51.03	52.69
Ash	4.16	19.02	10.97	18.04	11.43	6.38	8.18	6.08
Sulphur	.46	.58	.46	.72	1.15	.60	.46	.83
Loss of moisture on air drying	4.50	2.30	2.50	1.90	2.30	3.50	4.10	2.90
Analysis of air-dried sample:								
Moisture	8.63	4.14	7.25	3.75	2.51	6.52	5.12	2.37
Volatile matter	34.60	32.64	33.20	33.41	34.37	34.60	33.14	37.11
Fixed carbon	52.42	43.75	48.30	44.45	51.42	52.27	53.21	54.27
Ash	4.35	19.47	11.25	18.39	11.70	6.61	8.53	6.25
Fuel ratio	1.52	1.34	1.45	1.33	1.50	1.51	1.61	1.46

Proximate analyses of coals from the Book Cliffs coal field, Colorado-Utah—Continued.

I. Sec. 34, T. 10 S., R. 98 W.; Colorado.
II. Do.
III. Do.
IV. Upper coal, sec. 3, T. 11 S., R. 98 W.
V. Do.
VI. Secs. 3-4.
VII. Do.
VIII. Do.
IX. Sec. 6, T. 11 S., R. 98 W.
X. Sec. 8, T. 10 S., R. 99 W.
XI. Do.
XII. Do.
XIII. Do., first coal below upper coal.
XIV. Sec. 7, T. 10 S., R. 99 W.
XV. Sec. 1, T. 10 S., R. 100 W.; weathered sample.
XVI. Sec. 36, T. 9 S., R. 100 W.
XVII. Sec. 35, T. 9 S., R. 100 W.; weathered sample.
XVIII. Sec. 5, T. 9 S., R. 100 W.
XIX. Sec. 27, T. 8 S., R. 101 W.
XX. Sec. 29, T. 8 S., R. 101 W.
XXI. Sec. 30, T. 8 S., R. 101 W.
XXII. Sec. 18, T. 8 S., R. 101 W.
XXIII. Sec. 16, T. 7 S., R. 102 W.; 21-foot coal bed; weathered sample.
XXIV. Sec. 11, T. 7 S., R. 104 W.; on east side of gulch opposite mine.
XXV. Carbonera, sec. 14, T. 7 S., R. 104 W.
XXVI. Do.
XXVII. Do.
XXVIII. 1½ miles northwest of Nash ranch, T. 20 S., R. 21 E., Utah.
XXIX. 5 miles north of Thompsons.
XXX Do.
XXXI. 6 miles northeast of Solitude.
XXXII. 4 miles east of Woodside.
XXXIII. 7½ miles south of Sunnyside.
XXXIV. Do.
XXXV. West side of Horse Canyon, 6 miles south of Sunnyside.

Ultimate analyses of coals from the Book Cliffs coal field.

	I.[a]	V.	VI.	IX.	X.	XVIII.	XIX.
Laboratory No.	3550.	3546.	3541.	3545.	3490.	3640.	3587.
Analysis of sample as received:							
Hydrogen	5.45	5.50	5.26	5.82	5.46	5.39	5.94
Carbon	65.52	69.47	68.43	62.19	61.84	70.18	68.47
Nitrogen	1.20	1.56	1.55	1.40	1.07	1.20	1.56
Oxygen	16.50	16.79	17.92	23.95	20.95	17.01	17.29
Sulphur	.60	.72	.85	.63	.84	.49	1.02
Ash	10.73	5.96	5.99	6.01	9.84	5.73	5.72
Calorific value determined:							
Calories	6,466	6,913	6,838	6,034	6,166	6,894	6,811
British thermal units	11,639	12,443	12,308	10,861	11,099	12,409	12,260
Loss of moisture on air drying	4.30	2.20	2.00	4.40	5.60	0.20	5.50
Analysis of air-dried sample:							
Hydrogen	5.19	5.38	5.14	5.58	5.13	5.38	5.64
Carbon	68.46	71.03	69.83	65.05	65.51	70.32	72.46
Nitrogen	1.26	1.60	1.58	1.47	1.13	1.20	1.65
Oxygen	13.25	15.16	16.47	20.96	16.92	16.87	13.12
Sulphur	.63	.74	.87	.66	.89	.49	1.08
Ash	11.21	6.09	6.11	6.28	10.42	5.74	6.05
Calorific value determined:							
Calories	6,757	7,069	6,978	6,312	6,532	6,908	7,207
British thermal units	12,162	12,723	12,559	11,361	11,757	12,434	12,973
Carbon-hydrogen ratio	13.00	13.20	13.59	11.66	12.77	13.07	12.85

	XX.	XXI.	XXV.	XXIX.	XXXIV.	XXXV.
Laboratory No.	3585.	3586.	3729.	3856.	4013.	4015.
Analysis of sample as received:						
Hydrogen	5.81	5.54	5.63	5.01	4.97	5.26
Carbon	68.84	67.48	58.42	59.10	62.22	71.22
Nitrogen	1.55	1.57	1.24	1.32	1.25	1.29
Oxygen	17.45	17.99	19.83	14.97	22.92	15.32
Sulphur	1.30	1.26	.48	.58	.46	.83
Ash	5.05	6.16	14.40	19.02	8.18	6.08
Calorific value determined:						
Calories	6,809	6,771	5,815	5,890	6,035	7,239
British thermal units	12,256	12,188	10,467	10,602	10,863	13,030
Loss of moisture on air drying	5.20	3.60	4.50	2.30	4.10	2.90
Analysis of air-dried sample:						
Hydrogen	5.52	5.33	5.37	4.86	4.71	5.09
Carbon	72.62	70.00	61.17	60.49	64.88	73.35
Nitrogen	1.63	1.63	1.30	1.35	1.30	1.34
Oxygen	13.53	15.34	16.58	13.23	20.11	13.12
Sulphur	1.37	1.31	.50	.60	.47	.85
Ash	5.33	6.39	15.08	19.47	8.53	6.25
Calorific value determined:						
Calories	7,182	7,024	6,089	6,029	6,293	7,455
British thermal units	12,928	12,643	10,960	10,852	11,327	13,419
Carbon-hydrogen ratio	13.16	13.13	11.39	12.45	13.77	14.41

[a] For localities see preceding table.

The analysis of each coal is tabulated in two forms, showing the composition of the sample as received at the laboratory, representing the condition of the coal in the mine, and of the air-dried sample. Proximate analyses were made of each sample and ultimate analyses of 13 that were representative.

The fuel ratios, the quotient obtained by dividing the percentage of fixed carbon by the percentage of volatile combustible matter, range from 1.12 to 1.61, with an average of 1.43. Fuel ratios, however, are not a satisfactory guide for classification of bituminous coals and the ratio proposed by Campbell [a] is better, though the final classification is yet to be formulated. Campbell's classification is based on the carbon-hydrogen ratio, obtained by dividing the percentage of carbon by the percentage of hydrogen determined by ultimate analyses of air-dried samples. The carbon-hydrogen ratios of the 13 coals from the eastern Book Cliffs field given in the second table range from 11.39 to 14.41, with an average of 12.96. Comparison with the coals analyzed at the St. Louis fuel-testing plant shows that the Book Cliffs product falls into the same class with Indian Territory coals, the better grade of Illinois coals, and those from Kansas, Missouri, and Kentucky.[b]

On the basis of a comparison of calorific values the position of the coals under consideration is indicated by the following table:

Calorific values of various coals.

[Determined with Mahler bomb calorimeter on air-dried samples.]

	Coal.	Per cent of ash.	British thermal units.
1	Pocahontas, W. Va. (West Virginia No. 10) [c]	4.63	15,190
2	Windber, Pa. (Pennsylvania No. 1) [c]	7.41	14,499
3	Near Durango, Colo. [d]	5.31	13,816
4	Kemmerer mine No. 1, Frontier, Wyo. [e]	3.72	13,449
5	*Book Cliffs field*, No. XXXV (highest of 13 tests)	6.25	13,419
6	Newcastle, Colo. [f]	5.09	13,394
7	Warrior field, Alabama (Alabama No. 1) [c]	12.64	12,958
8	McAllister bed, Indian Territory (Indian Territory No. 3) [c]	11.28	12,469
9	*Book Cliffs field* (mean of 13 tests)	8.69	12,161
10	American Fuel Co., Gallup, N. Mex. (subbituminous) (New Mexico No. 1) [c]	7.10	11,435
11	Marion County, Iowa (Iowa No. 2) [c]	16.99	11,182
12	Belleville field, Illinois (Illinois No. 4) [c]	11.85	10,991
13	*Book Cliffs field* (lowest of 13 tests)	19.47	10,852
14	Cambria, Wyo. (Wyoming No. 2) [c]	26.26	10,364
15	Belt, Mont. [g]	20.88	10,139
16	Williston, N. Dak. (lignite) (North Dakota No. 2) [c]	6.71	9,491

[a] Campbell, M. R., Prof. Paper U. S. Geol. Survey, No. 48, pt. 1, 1906, pp. 156-173.
[b] Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, p. 169.
[c] Prof. Paper U. S. Geol. Survey No. 48, 1906.
[d] Report by M. K. Shaler, this volume, p. 423.
[e] Veatch, A. C., Bull. U. S. Geol. Survey No. 285, 1906, p. 339.
[f] Report by H. S. Gale, this volume, p. 300.
[g] Report by C. A. Fisher, this volume, p. 171.

The results were all obtained in the fuel-testing laboratory at St. Louis on air-dried samples of coal. Percentages of ash are also inserted in the table, for ash is so much inert matter and the calorific values would be misleading without a knowledge of its amount. As an illustration, recalculation on an ash-free basis of coals from the Book Cliffs field, Nos. 5 and 13 in the above table, gives, respectively, 14,310 and 13,475 British thermal units. On such a basis the values for the coals from Belt, Mont., and Cambria, Wyo. (Nos. 15 and 14), which contain considerable ash, would be much increased. The coal from Frontier, Wyo. (No. 4), ranks high because of its small ash content.

No systematic tests have been made of the coking quality of the coals in the eastern part of the Book Cliffs field, although attempts have been made to coke the Cameo and Palisades coals, but thus far with poor results. On the other hand, the coal from the Sunnyside mine, at the west end of the area under discussion, is coked. It remains to be determined what coals in this field will coke and what will not. It should be noted in this connection that whether a given coal will coke or not depends largely on the methods used. Coals which have been considered noncoking have been coked under proper treatment.

To judge from the analyses, therefore, the Book Cliffs coals are medium-grade bituminous and compare favorably with the product from the Rocky Mountain region and the Mississippi Valley.

DEVELOPMENT.

Very little has been done in developing this area. There are only four mines with railroad connection and practically their entire product is used by the towns of Grand Junction, Palisades, and Fruita, and by the Uinta Railroad. These mines are the Cameo (No. 1), Palisades (No. 6), Book Cliff (No. 10), and Carbonera (No. 26). They are reported to have produced in 1905 a total of only 50,000 tons; the other mines shown on the map are for the most part country banks that yield a few hundred tons each year. At present the local market is the only outlet, but with the equalization of freight rates on the Denver and Rio Grande Railroad, which extends along the lowland at the base of the Book Cliffs, it probably will not be long before this great coal reserve will be more actively developed.

The following is a list of the mines and prospects in this area. The numbers correspond to those used on the map (Pl. XVIII).

1. Cameo mine.
2. Prospect on upper coal.
3. Mount Lincoln mine.
4. Riverside mine.
5. Prospect on upper coal.
6. Palisades mine.
7. Garfield mine.
8. Prospect on lower coal.
9. Old Book Cliff mine.
10. Book Cliff mine.
11. Keystone or Steele mine.
12. Black Diamond mine.
13. Farmer's mine.
14. Bob Cat mine.
15. Excelsior mine.
16. Corcoran mine.
17. Hunter mine.
18. Kiel or Gross mine.
19. Nugent mine.
20. Nearing mine.
21. Mott prospect.
22. Johnson mine.
23. Lane mine.
24. Prospect.
25. Prospect.
26. Uinta Railroad Company's mine.
27. Coal outcrop.
28. Coal outcrop.
29. Prospect.
30. Ballard mine.
31. Black Baby mine.
32. Petersen's prospect.
33. Prentiss prospect.
34. Prentiss prospect.
35. Horse Canyon mine.

THE DURANGO COAL DISTRICT, COLORADO.

By JOSEPH A. TAFF.

INTRODUCTION.

The geology and coal resources of the Durango district are generally well known. Reconnaissance surveys were made through the eastern part of the district in 1905 and through the western part in 1906, in the progress of a survey of the Durango-Gallup coal field. Reports of this reconnaissance work are found in the Contributions to Economic Geology for 1905 and 1906.[a]

During September and October, 1906, the writer had occasion to map the base of the coal-bearing strata of the Mesaverde formation between Florida and Mancos rivers and the base of the Laramie formation from Animas to Florida River. This mapping was done by stadia measurements, a method that permits an accuracy of location both of coal areas and of mines and prospects that is not obtainable by more rapid reconnaissance methods.

The chief purposes in presenting this paper simultaneously with the report of reconnaissance surveys are to publish the map showing accurately the boundaries of the coal land and to discuss more fully the development of the coals.

TOPOGRAPHY.

The country indicated by the map (Pl. XIX) as the Durango district lies just off the southern foothills of the San Juan and La Plata mountains. The uplifts of these mountains have tilted the rocks steeply toward the south along the northern border of the area. Farther south, toward the center of the Durango-Gallup basin, the tilting of the rocks grows gradually less.

In general conformity with the southward tilting of the strata there is a corresponding but lower incline of the land surface. Along the southern foothills of the mountains there is a steeply inclined plain underlain and controlled in its northern part by the Dakota sandstone. This plain grows gradually narrower toward the east with

[a] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285 1906, pp. 241-258. Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field, this bulletin, pp. 376-426.

the increasing steepness of the dip of the rocks. It extends over the edge of the Mancos shale with gradually decreasing slope southward to the base of the Mesaverde escarpment. This escarpment is made by the outcropping edge of the Mesaverde sandstone, which includes the lowest group of workable coal beds in the district. The position of the crest of the escarpment is shown on the map by the line indicating the outcrop of the lowest workable coal bed. A second broad plain slopes southward from the top of the Mesaverde scarp, its southern limit being the escarpment formed by the outcrop of the Laramie sandstone. The rocks gradually increase in dip toward the east through the Durango district, and there is a corresponding increase in the slope of this plain in the same direction.

The Laramie escarpment, which is similar to that of the Mesaverde, is located on the map by the line designating the outcrop of the lowest workable Laramie coal bed. This escarpment is due to the outcrop of the Laramie sandstones. The Lewis shale crops out below the Laramie on the north, making steep slopes beneath the sandstone cliffs. On the south side of the scarp the slopes are more gradual, yet steep, and beyond the sandstones softer rocks make extensive flat areas.

The larger streams, Animas and La Plata rivers, flow southward across the escarpments and intervening plains with little change of grade. The valleys are relatively narrow and deep at the crossing of the escarpment ridges. Through plains of soft strata they are wider and more shallow, yet the sides are steep.

The two outliers, Perrine Peak and Barnroof Point, in the northern part of T. 35 N., Rs. 9 and 10 W., are mesas capped by Mesaverde sandstone. The cliffs are high and in places impassable, especially on the north and east.

A considerable part of the Dolores Plateau to the north of the coal area contains forests of pine. There are also considerable growths of merchantable pine on the rougher sandstone surfaces of the Mesaverde northwest of Porter, toward the head of Hay Gulch, on the borders of Cherry Creek Canyon, and on branches of East Canyon southeast of Mancos. Elsewhere in this district the vegetation consists of piñon, juniper, scrub oak, and various other kinds of brush.

STRATIGRAPHY.

There are two formations of coal-bearing rocks in the Durango district—the Laramie and the Mesaverde. Each consists of sandstone, shale, and coal, and each has an aggregate thickness of several hundred feet. The coal beds occur in the midst of and interbedded with the sandstone and shale. The Laramie formation is the younger, but both are of Cretaceous age.

Massive white sandstone beds lie just below the lowest workable coal beds in the Laramie. This sandstone makes cliffs in the ridges and escarpments and forms a pronounced feature of the landscape.

The mammoth coal bed once mined at Carbon Junction and the beds of the abandoned La Plata mine southeast of Durango lie just above this massive sandstone. Sandstone beds interstratified with shale occur above the workable coal beds of the Laramie for a distance of several hundred feet.

The Laramie is separated from the Mesaverde formation below by the Lewis shale, 1,600 feet thick. This shale makes broad stretches of flat country between the basal boundary lines of the Laramie and Mesaverde coals shown on the map.

The Mesaverde formation has in its upper part pronounced sandstone layers interbedded with shale and some thin coal beds. A central member consists of shale, beds of workable coal, and sandstone. The shale or shaly beds on the whole are more pronounced than the sandstone strata. There are three and in places four workable beds of coal in this central part of the Mesaverde. Very near and below the workable coal beds there are thick whitish sandstone beds comparable to the thick white sandstone in the lower part of the Laramie formation. These sandstone beds show in almost continuous outcrops that are unfailing keys to the presence of the coal beds. Below the thick sandstone there is a gradation through successively thinner sandstone layers down to the Mancos shale. The Mesaverde formation has a total thickness of nearly 1,000 feet.

The Mancos shale, underlying the Mesaverde, is about 1,200 feet thick. Like the Lewis shale, the Mancos is soft rock. It outcrops in valley and plateau lands north of the Mesaverde escarpment. It is underlain by the Dakota sandstone, which contains locally workable coal beds. In the area mapped, however, the coal is not known to be of any value and is not considered in this report.

STRUCTURE.

FOLDS.

All the coal-bearing rocks in the Durango district are tilted downward toward the south and southeast. The dip of the rocks varies from place to place, increasing northward toward the mountains and also eastward along the outcrop of the formations. In the western part of the district the dip is fairly regular, 4° to 5° toward the south. In the vicinity of Hesperus, near the northern outcrop of the Mesaverde coals, the dip is nearly 8°. Within a few miles to the south the dip diminishes to 4° and continues with slight decrease down Hay Gulch to La Plata River. Local warping of the strata between Durango and Hesperus has produced lower southward dips of the rocks near the outcrop of the Mesaverde coals. The dips increase gradually eastward from 6° near Porter to 40° on Florida River 6 miles northeast of Durango.

The rocks in the central part of T. 35 N., R. 10 W., have been warped into a very shallow fold 2 to 3 miles in width, which is tilted

slightly toward the southwest. The Perrine Peak mine, near the north side of sec. 14, T. 35 N., R. 10 W., is in the central part of this fold. Farther east by way of Durango the dip changes to southeasterly and gradually increases, finally attaining an angle of 36° to 40° near the eastern boundary of the area mapped.

In the southeastern part of the district, in a belt of country generally following the outcrop of the Laramie coals, the rocks are tilted to the southeast at a slightly greater angle than farther west. By reference to the map it will be seen that the dips change gradually along the Laramie coal outcrop, from 8° at the southern edge of the area to 45° on Florida River.

FAULTS.

Only a few faults have been observed in this district, and generally they are too small to interfere seriously with the mining of coal. The rocks are exposed so extensively that faults of large amount would be detected. In the Durango district there are two kinds of normal or tension faults. One is the ordinary type, in which the rocks on one side have been dropped down with respect to those on the other side along a nearly vertical plane of fracture; in the faults of the other type the plane of movement is nearly horizontal.

Two faults of the first class occur near Durango. One is just west of the Gold King mine, in the northeast corner of sec. 32, T. 35 N., R. 9 W. This fault crosses the gulch in a northerly direction and has a throw of about 60 feet. Another fault of this class occurs in the western part of the Gold Prince mine, in the NE. ¼ sec. 31, T. 34½ N., R. 9 E. This fault bears in a northeast direction and has thrown the rocks down toward the southeast. It has been overcome in the mine, however, and mining continued west of it. Several small faults are encountered in the mines at Porter and at Perrine Peak. None of these, however, have displaced the rocks more than a few feet. Three faults were noted in the Hesperus mine, bearing N. 20° W. The greatest displacement observed was 33 feet.

Tension faults of the other class were noted in the cliffs near the north end of the Perrine Peak mesa, in sec. 11, T. 35 N., R. 10 W. In these faults the plane of fracture is nearly horizontal, and the rocks above the break appear to have moved northward with respect to the rocks below. The displacement in all cases is slight and would not seriously affect coal-mining operations.

COALS.

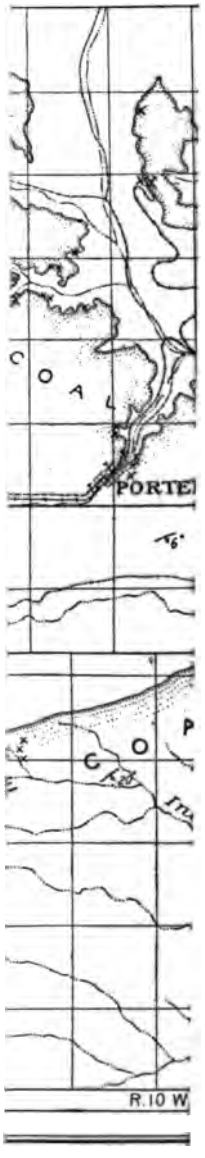
LARAMIE COAL.

There are two grades of coal in the Durango district. One occurs in the upper or Laramie formation and the other in the Mesaverde formation. The location of the lowest workable bed in the Laramie is shown on the map. This coal, of which there are several beds, is of medium to low grade. It is classed as subbituminous coal (black

es

beds
l groups

.10 W.



lignite). It is dull black in color and softer than the ordinary bituminous coal, but like that grade it mines in cubical or block form. When exposed to the weather for a considerable time it gives out and reabsorbs more moisture under varying conditions of the atmosphere than the coals of higher grade, and will finally slack, the blocks breaking down into small lumps or particles. It is considerably lighter than the better bituminous coals, and when fired in the locomotive a large part of the smaller fragments of coal are driven out in the blast. Moreover, a considerable percentage will pass through the grates that are used in burning bituminous coal of better grades, owing to its softness and tendency to slack. The Laramie coals in this region contain many partings of shale or bone. This is especially true of the lower and thicker of the workable beds. In mining, these partings can not be entirely eliminated from the marketable coal. Certain variable and thin bony streaks also are an inseparable part of the coal bed and give it a high percentage of ash. Coals of this class, however, mined in the region of Sheridan, Wyo., are used very extensively and successfully by locomotives with specially constructed grates.

The coals of the Laramie formation have been mined to a considerable extent in sec. 27, T. 35 N., R. 9 W.; at Carbon Junction, in sec. 4, T. 34 N., R. 9 W., 3 miles south of Durango, and to a smaller extent at a number of other localities in the Durango district. None of the beds are worked at present, however, on account of the abundance of better coal in this district.

MESAVERDE COAL.

The other class of coal in the Durango district occurs in the Mesaverde formation. The outcrop of the lowest workable bed in this formation and also all the mines and prospects on the different beds occurring in the formation are shown on the map. It is known that there are three and in places four workable coal beds in the Mesaverde formation. The coals in the different beds vary in quality slightly from place to place. The beds that have been mined for a number of years at Porter are the best of this class that are known in the district. They carry a good grade of coking coal, which is coked at Porter and Durango. The coke is utilized chiefly for smelting purposes.

The coal that is mined at Hesperus can not be coked successfully by the methods in use at present, but it is reported to have been coked under more favorable conditions. All the coals, however, that are mined at present at Durango, Porter, Perrine Peak, Hesperus, and in the vicinity of Mancos are high-grade bituminous coals, and are classed as excellent fuels for locomotive and domestic use. The coal mines in cubical or block form, but some of it is reported to produce considerable slack. This slack, however, is converted into coke or is utilized in stationary engines and for domestic purposes.

COMPOSITION OF THE COALS.

Samples of the coals were collected from the various mines in the district and shipped in sealed cans to the United States Geological Survey fuel-testing plant at St. Louis, where analyses were made. Care was taken to see that each sample was representative of that part of the bed which was mined, if the coal was divided into benches by shale or bone partings. Where the bed was unbroken by partings the sample was taken so as to represent an average of the entire bed. In each case a section of clean coal was cut completely across the workable coal, broken into small fragments, mixed thoroughly, quartered, alternate quarters rejected, mixed and quartered again until the desired amount was obtained. This was inclosed in the can and sealed in the mine or prospect for shipment. The results of the analyses are stated in the subjoined table:

Analyses of coal samples from Durango district, Colorado.

[F. M. Stanton, chief chemist.]

Locality.	Three miles northwest of Durango.	Near Durango.	Three miles southeast of Durango.	Near Durango.	Hesperus.	Near Mancos.	Near Mancos.	Porter.
Laboratory No.	3552.	4174.	3551.	4113.	7573.	4225.	3991.	2092.
Analysis of sample as received:								
Prox. Moisture	3.64	2.70	3.05	1.41	5.55	5.44	6.12	2.73
Prox. Volatile matter	37.79	32.75	32.70	33.27	36.23	38.71	35.86	36.65
Prox. Fixed carbon	53.35	59.82	47.47	55.97	52.53	50.10	49.44	54.48
Prox. Ash	5.22	4.73	16.78	9.35	5.69	5.75	8.58	6.74
Ult. Sulphur	1.36	.69	1.30	.58	.64	1.01	.63	.53
Ult. Hydrogen	5.39	.....	4.73	.....	5.46	5.80	.....	.....
Ult. Carbon	75.40	.....	64.21	.....	72.70	72.26	.....	.....
Ult. Nitrogen	1.48	.....	1.43	.....	1.37	1.47	.....	.....
Ult. Oxygen	11.15	.....	11.55	.....	14.14	13.71	.....	.....
Calorific value determined:								
Calories	7,553	.....	6,611	.....	7,289	7,170	.....	7,730
British thermal units	13,595	.....	11,900	.....	13,120	12,906	.....	13,914
Loss of moisture on air drying	1.60	1.70	.90	.40	2.30	2.00	2.50	1.30
Analysis of air-dried sample:								
Prox. Moisture	2.07	1.02	2.17	1.01	3.33	3.51	3.71	2.46
Prox. Volatile matter	38.40	33.32	33.00	33.40	37.08	39.50	36.78	37.13
Prox. Fixed carbon	54.22	60.86	47.90	56.20	53.77	51.12	50.71	55.19
Prox. Ash	5.31	4.81	16.92	9.38	5.82	5.87	8.80	6.82
Ult. Sulphur	1.38	.70	1.31	.58	.66	1.03	.64	.54
Ult. Hydrogen	5.20	.....	4.67	.....	5.32	5.69	.....	.....
Ult. Carbon	76.63	.....	64.79	.....	74.41	73.73	.....	.....
Ult. Nitrogen	1.50	.....	1.45	.....	1.40	1.50	.....	.....
Ult. Oxygen	9.89	.....	10.85	.....	12.39	12.18	.....	.....
Calorific value determined:								
Calories	7,676	.....	6,671	.....	7,461	7,316	.....	.....
British thermal units	13,816	.....	12,008	.....	13,429	13,163	.....	.....

DETAILED DESCRIPTION OF COAL BEDS BY TOWNSHIPS.

LARAMIE COAL.

T. 35 N., R. 9 W.—Of the two principal coal beds of the Laramie formation that have been mined and prospected in the district, a number of exposures have been made in the southeastern part of this township. A small mine was located on one of these beds and con-

siderable coal has been removed, as shown by slack on the dump, but the opening was closed and a section of the bed could not be obtained.

Another prospect has been made in the east side of the SE. ¼ sec. 23. The coal bed is tilted strongly toward the southeast. The prospect is in the form of a shallow pit across the bed. The following is a section of the coal:

Section of coal bed in SE. ¼ sec. 23, T. 35 N., R. 9 W.

	Ft.	in.
Coal	6	
Shale		10
Coal	4	
Shale		7
Coal	3	
Shale	1	
Coal	1	3
Shale	5	
Bone and shale	4	
Coal	1	9
Shale		3
Coal	1	8
	29	4

A prospect in the NW. ¼ NE. ¼ sec. 26 was made a number of years ago and the section of the coal is concealed by caving of the earth.

Both the upper and the lower beds have been worked at what was known as the La Plata mine in the SW. ¼ SE. ¼ sec. 27. The lower bed of coal was on fire at the time this investigation was made and a full section could not be obtained. A section of the upper bed is as follows:

Section of upper coal bed in the SW. ¼ SE. ¼ sec. 27, T. 35 N., R. 9 W.

	Ft.	in.
Shale roof.		
Coal	1	2
Bone		4
Coal	3	
Bone	1	
Coal	1	9
Shale floor.		
	7	3

The lower coal occurs about 75 feet below the upper. It is a much thicker bed, but contains many shale and bone partings.

The lower Laramie coal has been mined in the NW. ¼ sec. 34, and for a considerable time the coal was hauled by wagon to Durango. Operations here ceased a number of years ago, and the earth had fallen in the entry, so that a section of the coal could not be made.

T. 34½ N., R. 9 W.—A prospect on the upper coal is located in the SE. ¼ sec. 33, T. 34½ N., R. 9 W. The prospect was partially filled and

only the upper 6 feet of the bed could be seen. The coal was massive and appeared to be of average grade for this class.

T. 34 N., Rs. 9–11 W.—Considerable mining has been done on the lower bed at Carbon Junction, on the east side of sec. 4, T. 34 N., R. 9 W. This bed is virtually a group of coal beds separated by thin bands of shale and bony coal. Several of these separate benches are of workable thickness. The following is a section of the bed at Carbon Junction:

Section of lower coal bed at Carbon Junction, in sec. 4, T. 34 N., R. 9 W.

	Ft.	In.
Coal, bony	3	
Coal		8
Coal, bony	2	2
Coal	1	3
Shale		5
Coal	1	
Bone		7
Coal	1	6
Bone	1	
Coal	1	6
Shale		5
Coal	2	
Bone		2
Coal		9
Bone	2	
Coal	1	4
Shale, black	1	
Coal		10
Shale, black		8
Coal	2	
Shale	6	5
Coal	3	6
Sandstone		1
Coal, bony	2	9
Coal	3	6
Bone		5
Coal	2	
Shale, black	2	
Coal	5	
	49	11

Prospects on these coal beds have been made in the S. ½ sec. 8, T. 34 N., R. 10 W.; and in the NE. ¼ sec. 13 and SW. ¼ sec. 34, T. 34 N., R. 11 W. They show the continuation of the coal beds across the Durango district.

MESAVERDE COAL.

T. 35 N., R. 9 W.—A prospect on one of the Mesaverde coal beds lies in the SE. ¼ sec. 14, but a section of fresh coal could not be obtained.

Several abandoned mines are located in secs. 22, 27, and 28, near the road on the southeast side of the ridge made by the Mesaverde sandstones. The coal was obtained at these localities by tunnels driven northwestward horizontally through the overlying sandstones. The coal was hauled by wagon to Durango. With the exception of the one in the SW. ¼ SE. ¼ sec. 21, these mines had fallen into decay and a satisfactory section of the coal beds could not be obtained. The section at the location just cited is as follows:

Section of coal bed in SW. ¼ SE. ¼ sec. 21, T. 35 N., R. 9 W.

	Ft.	in.
Shale roof.		
Coal		10
Bone		2
Coal		11
Bone		2
Coal		2
	2	3

The prospects located in the NW. ¼ NE. ¼ sec. 28 also show 2 feet 3 inches of coal.

Mining operations are being actively carried on at what is known as the Gold King mine, located in the southwest corner of sec. 28, on one of the upper beds of this formation. The coal is mined by a drift driven on the strike of the coal bed toward the northeast. Entries have been driven to the north 1,700 feet and to the south 1,200 feet, and rooms are turned both to the right and left. The coal dips toward the southeast at an angle of 18°. A section of the bed in the mine is as follows:

Section of coal bed in Gold King mine, in sec. 28, T. 35 N., R. 9 W.

	Ft.	in.
Sandstone roof.		
Coal	2	5
Shale		2
Sandstone floor.		

The bed varies in thickness from place to place in the mine. It is reported to average about 2 feet 10 inches.

A lower bed has been opened across the gulch from the Gold King mine, in the NE. ¼ sec. 32. The coal is in two benches. The following section is exposed at the opening:

Section of coal bed in NE. ¼ sec. 32, T. 35 N., R. 9 W.

	Ft.	in.
Shale roof.		
Coal	2	8
Shale with thin coal	9	6
Coal	2	6
Shale floor.		

Another bed about 75 feet lower in the section is exposed on the north side of the gulch, in the northeast corner of sec. 32. A section of the bed is as follows:

Section of coal bed in sec. 32, T. 35 N., R. 9 W.

	Ft.	in.
Coal		6
Shale		4
Coal	1	3
Shale		5
Coal		6
Sandstone floor.		
	3	

A number of coal beds in the lower part of the Mesaverde formation have been prospected and mined to a considerable extent on both sides of Animas River, in the southern part of sec. 32. The beds are much thinner than those occurring higher up, and mining has not been found profitable in the presence of thicker beds.

A prospect in the NW. ¼ SE. ¼ sec. 31 shows 3 feet 6 inches of coal. Another coal is opened in the SE. ¼ sec. 31, and shows the following section:

Section of coal bed in SE. ¼ sec. 31, T. 35 N., R. 9 W.

	Ft.	in.
Sandstone, shaly.		
Coal		5
Shale	1	
Coal	2	
Shale, carbonaceous, floor.		
	3	5

Two mines not now in operation are located in the NW. ¼ sec. 31 on what appears to be the same bed, which has a thickness of 4 feet 7 inches of clean coal. The same coal bed has been mined for a number of years near the south side of sec. 30, but is now abandoned. The coal was delivered over an incline leading northward to Lightner Creek valley. It is reported that the coal in this mine has been removed through the ridge to the south, to the mine above mentioned, located in the NW. ¼ sec. 31.

One of the upper beds of the Mesaverde is now being mined actively in the NE. ¼ sec. 6, T. 34½ N., R. 9 W., very near the south line of T. 35 N., R. 9 W. The mine here is locally known as the Gold Prince, also as the Champion mine, and is under the control of the Gold King Mining Company. The coal in the Gold Prince mine is reported by the operators to range between 3 and 4 feet in thickness of clear coal. An examination of the working face made in October, 1906, showed that the bed ranges in thickness between 2½ and 3½ feet. The coal dips about 18° SE. The bed has a sandstone roof and floor.

A prospect is located in the NW. ¼ SE. ¼ sec. 31, T. 35 N., R. 9 W., on what is probably a lower bed than that mined at the Gold Prince. The following is a section at this locality:

Section of coal bed in the NW. ¼ SE. ¼ sec. 31, T. 35 N., R. 9 W.

	Ft.	in.
Sandstone roof.		
Shale		4
Coal		3
Bone		2
Coal	4	2
Shale	1	6
Coal		7
	7	

In the SE. ¼ SE. ¼ sec. 31 a prospect shows a coal bed 3 feet 6 inches thick without partings.

T. 35 N., R. 10 W.—The Porter mines, three in number, are located in secs. 34 and 35, on three separated beds of coal. A section of these beds as at present mined is as follows, in descending order:

Section of coal beds at Porter, in secs. 34 and 35, T. 35 N., R. 10 W.

	Ft.	in.
No. 1.		
Coal, bony, roof overlain by sandstone.		
Coal	2	4
Shale, sandy.		
Shale and sandstone	75	
No. 2.		
Shale.		
Coal	1	1½
Bone		9
Coal	2	6
Shale and sandstone	30	
No. 3.		
Coal		10
Shale	1	
Coal	4	
Bone		2
Coal	2	7½
Shale, followed below by massive sandstone.		

The lowest bench of coal, 2 feet 7½ inches thick, is the only part of bed No. 3 at present mined. Bed No. 1 is mined near the center of the SE. ¼ sec. 34. Beds Nos. 2 and 3 are worked in the mine located near the center of the east side of sec. 34, and No. 3 alone is worked in the third mine, located in the NW. ¼ sec. 35. The principal operations are in bed No. 3. Its main entry is driven northward through the hill and across the gulch.

Several prospects are located on the south side of the valley of Lightner Creek, in sec. 22. At a small mine in the SE. ¼ SW. ¼ NW. ¼

sec. 22, worked intermittently, the coal bed is 4 feet 4 inches thick without partings. This bed appears to be the same as No. 3, or the lowest bed in the Porter mines.

The prospect on Lightner Creek in the NE. ¼ NW. ¼ sec. 22, apparently on the same bed as Porter bed No. 3, shows 5 feet 11 inches of clean coal. A higher bed has been prospected at the same locality, but the section could not be seen.

Three coal beds have been prospected in the forks of Lightner Creek in the NE. ¼ sec. 21. A section of the coal and intervening rocks is as follows, in descending order:

Section of coal beds in NE. ¼ sec. 21, T. 35 N., R. 10 W.

	Ft.	in.
Upper bed:		
Coal		7
Shale		7
Coal	2	7
Shale and sandstone.		
Middle bed:		
Shale roof, 6 inches, overlain by sandstone.		
Coal	4	9
Shale floor.		
Sandstone and shale	80	
Lower bed:		
Coal	2	3

The lower bed outcrops 30 feet above the base of the gulch.

A coal mine has recently been opened near the center of the E. ½ sec. 21, in the east side of the valley, and the entry is driven toward the east. The bed here appears to be the same as No. 3 of the Porter mines. The section of coal is as follows:

Section of coal bed in E. ½ sec. 21, T. 35 N., R. 10 W.

	Ft.	in.
Sandstone roof.		
Coal	3	9
Bone		5
Coal		4
	4	6

Twenty-five feet higher in the rocks a coal bed probably equivalent to No. 2 of the Porter mines is exposed and shows the following section:

Section of coal bed in E. ½ sec. 21, T. 35 N., R. 10 W.

	Ft.	in.
Coal		4
Bone		2
Coal	1	
	1	6

A coal bed, probably No. 3 of the Porter mines, is prospected at the center of the north side of the NE. ¼ sec. 21, where it has a thickness of 4 feet 11 inches without partings.

An old prospect in the NE. ¼ sec. 16 shows 2 feet of coal inclosed by beds of shale.

The Calumet Fuel Company has mines located on Perrine Peak mesa, in the N. ½ sec. 14. The Perrine Peak mine is served by a branch from the Rio Grande Western Railway in Lightner Creek valley. The coal is mined on the rise toward the northeast. The bed ranges in thickness between 2 feet 6 inches and 7 feet. The roof is shale, 1 to 2 feet thick, and requires careful timbering. In places a 5-inch shale parting appears near the base of the bed. The floor is sandstone. The section at the face of the first rise, 1,200 feet from the mouth of the mine, is as follows:

Section of coal bed in Perrine Peak mine in N. ½ sec. 14, T. 35 N., R. 10 W.

	Ft.	in.
Coal	6	10
Shale		6–8
Coal		3–12

A section of the same bed 250 feet from the mouth of the main entry is as follows:

Section of coal bed in Perrine Peak mine.

	Ft.	in.
Coal	5	11
Shale		7
Coal		4
	6	10

The following is a section of the same bed near the mouth of the main entry:

Section of coal bed in Perrine Peak mine.

	Ft.	in.
Coal, bony		9
Coal	5	8½
Shale		5
Coal		9
	7	7½

One of the Mesaverde coal beds having a thickness of 3 feet 3 inches of clean coal has been prospected in the SE. ¼ NE. ¼ sec. 16.

T. 35 N., R. 11 W.—Several prospects have been made and coal mined to a small extent in the NE. ¼ sec. 15, on the west side of La Plata River. Two workable coal beds are exposed at this locality, in approximately the positions of beds Nos. 1 and 2 in the Porter mines. The following is a section of the coal and associated rocks:

Section of coal beds in NE. ¼ sec. 15, T. 35 N., R. 11 W.

	Ft.	in.
Sandstone, shaly.		
Coal		3
Shale		4
Coal	3	9
Shale		10
Coal	1	9
Shale		3
Coal		6
Shale and sandstone	75	
Coal		8
Shale	8	
Coal	2	6
Shale	6	
Sandstone, thick.		

One of the lower beds in the Mesaverde formation has been mined extensively on the east side of the La Plata in the NE. ¼ sec. 14. These mines were abandoned, apparently for more favorable locations at Hesperus, in the southern part of the same section. They have fallen by decay, but the section at the main entry is shown as follows:

Section of coal beds in NE. ¼ sec. 14, T. 35 N., R. 11 W.

	Ft.	in.
Sandstone, shaly.		
Coal exposed (lower part of bed concealed)	5	
Shale and sandstone	100	
Shale roof to coal.		
Coal		6
Bone		3
Coal	6	2
Sandstone.		

One of these beds has been mined extensively near the south edge of sec. 12, in what is known as the Ute mine. Operations had ceased at this mine when an investigation of the coal was made, but the bed appears to correspond to No. 1 or No. 2 of the Porter section. The following is the section of the coal at the Ute mine:

Section of coal bed at Ute mine, sec. 12, T. 35 N., R. 11 W.

	Ft.	in.
Sandstone, white, exposed	20	
Shale roof.		
Coal	3	11
Bone		3
Coal	1	
Total coal bed	5	2

One of the lower coal beds of the Mesaverde formation is worked actively at Hesperus, in what is known as the Hesperus mine, which is under the same control as the mines at Porter. The bed has an average thickness of about 5½ feet. Locally it runs as high as 6½ feet and as low as 4 feet 10 inches. It is mined by slope toward the west.

The coal dips 12° S. near the entrance and about 8° at the face of the main slope. The roof of the coal is generally sandstone, but a selvage of shale occurs locally between the sandstone and coal. The floor is sandstone, with a few inches of carbonaceous shale or bone at the base of the coal.

Some of the upper coal beds of the Mesaverde formation have been prospected and mined for local consumption in Hay Gulch, in sec. 31, T. 35 N., R. 11 W., and sec. 36, T. 35 N., R. 12 W. One of these beds in the NW. ¼ NW. ¼ sec. 31 is 6 feet 8 inches thick and has a shaly sandstone roof. The same bed has been mined in the NE. ¼ sec. 36, T. 35 N., R. 12 W., but the operations are now abandoned and the coal is partially concealed, 2½ feet being exposed from the roof downward. A prospect on what is probably the same bed is located in the SE. ¼ NW. ¼ sec. 36, T. 35 N., R. 12 W. A short drift 20 feet in length has been driven on the coal. The section here is as follows:

Section of coal bed in SE. ¼ NW. ¼ sec. 36, T. 35 N., R. 12 W.

	Ft.	In.
Sandstone.		
Coal	1	
Bone		6
Coal	4	
Sandstone	20–30	
Total coal bed	5	6

The lower coal beds of the Mesaverde formation are exposed in natural outcrops in many places along the upper courses of Hay Gulch, in secs. 16, 17, 20, and 21, T. 35 N., R. 11 W. The crop of one of these coals in the NE. ¼ sec. 17 shows 4 feet of coal. A shallower prospect, located in the SW. ¼ SW. ¼ sec. 8, exposes 10 feet of coal apparently without any parting. The coal, however, is partially decomposed and its true character could not be determined.

T. 35 N., R. 12 W.—Coal has been prospected on the east side of Alkali Gulch near the Crawford ranch. The bed has a sandy-shale roof and shows 3 feet 9 inches of coal.

A number of natural coal outcrops were noted on the east side of Cherry Creek valley. In the SE. ¼ sec. 31 a coal bed in the upper part of the Mesaverde formation is exposed in a prospect and shows the following section:

Section of coal bed in the SE. ¼ sec. 31, T. 35 N., R. 12 W.

	Ft.	In.
Shale, white.		
Coal		2
Shale		4
Coal		3
Shale, black		4
Coal	3	
Shale and coal		4
Coal	2	6
Shale.		
	6	11

In the SE. ¼ NW. ¼ sec. 32, on the east side of Cherry Creek, ten different coal beds, two or three of which are workable, are exposed in a small gulch. The upper workable bed has the following section:

Section of coal bed in the SE. ¼ NW. ¼ sec. 32, T. 35 N., R. 12 W.

	Ft.	in.
Sandstone.		
Coal	3	4
Shale	1	3
Coal	1	10
	6	5

About 100 feet lower in the section is another workable coal bed, which has the following section:

Section of coal bed in the SE. ¼ NW. ¼ sec. 32, T. 35 N., R. 12 W.

	Ft.	in.
Shale.		
Coal	1	3
Sandstone		4
Coal	1	3
Shale.		
	2	10

Between the two beds above described there are two other beds in which the coal has a thickness of 2 feet. About 25 feet below the lower bed, whose section is given above, is another showing 2 feet of coal. All of the coal is weathered and a satisfactory interpretation of its quality can not be made.

T. 35 N., R. 13 W.—Several coal beds in the Mesaverde formation are exposed and active mining has been carried on in the W. ½ sec. 2, T. 35 N., R. 13 W. The mine now being worked, known as the Spencer mine, is located in the north face of the escarpment. An incline and spur of the Rio Grande Southern Railroad is being constructed from Mancos and it is planned to mine a large quantity of coal in the near future. Previously the output was hauled from the mines to Mancos by wagon and shipped principally to Telluride. The coal from this mine is especially sought for domestic fuel. Two workable beds are exposed in the same locality by prospect above the Spencer coal. The following is a section of the three coal beds with intervening rocks:

Section of coal beds at Spencer mine.

	Ft.	in.
Shale.		
Coal, bony	1	
Coal	1	1½
Bone		2
Coal	1	11
Sandstone and shale	30	
Shale.		
Coal	3	3
Sandstone	25	
Coal, Spencer bed	3	2
Shale.		

Natural exposures of the coal beds in the Mesaverde formation are of common occurrence on the headwaters of the western branch of East Canyon, south and east of the Spencer mine. In all these exposures the coal is considerably decomposed and it was not possible to determine its character, though the sections indicated workable thickness. The same beds are exposed at a number of places in sec. 36, on a branch of Cherry Creek. There were no fresh exposures in this locality, but the showing made by the beds indicated workable coal.

T. 36 N., R. 13 W.—What is believed to be the same bed that is worked at the Spencer mine has been recently opened in the NE. ¼ sec. 36, at the Wood mine. An entry about 100 feet in length has been driven on the coal at this place. The following section is shown at the face:

Section of coal bed at Wood mine, in NE. ¼ sec. 36, T. 36 N., R. 13 W.

	Ft.	In.
Shale and thin coal interstratified.		
Coal	1	4
Coal, shaly	5	5
Coal	3	
Bone		6
	10	3

THE PLEASANT VALLEY COAL DISTRICT, CARBON AND EMERY COUNTIES, UTAH.

By JOSEPH A. TAFF.

INTRODUCTION.

A reconnaissance survey of the Book Cliffs coal field in Carbon, Emery, and Sevier counties, Utah, was made by the writer in 1905. At the same time certain areas were surveyed more carefully for the purpose of classification, but the time allotted did not permit an accurate limitation of the coal land as a whole or a thorough study of the structure of the rocks.

During the season from April to September, 1906, the outcrop of the lowest workable coal in the sectioned areas of the same coal field were located by instrumental measurement and much additional information was gained regarding the character of the coal and the general structure of the rocks. The outcrop of the lowest workable coal was mapped as accurately as the land surveys would permit. This outcrop marks the boundary of the coal land and is shown on the accompanying map (Pl. XX).

In the Book Cliffs proper, which extend eastward from the vicinity of Castlegate, the later surveys produced but little information additional to that obtained in the previous reconnaissance work. The coal-bearing measures are admirably exposed in the bold and, for the most part, bare escarpments of the Book Cliffs and in the eastern edge of the Wasatch Plateau. The geology is simple, the rocks being almost flat. In Pleasant Valley, however, near the north end of the Wasatch Plateau, and in Huntington Canyon, lying immediately to the south, the surface features are smoother, especially in the more elevated parts, though deeply cut into canyons and gulches. Here the edges of the coal-bearing strata are concealed in a large measure by a mantle of soil and weathered rock. In addition, a more abundant growth of vegetation is found here than in the lower and more broken lands. The recent surveys in the Pleasant Valley district have added much to previous knowledge of the occurrence of coal and the faulted structure of the rocks.

LOCATION.

The area here designated as the Pleasant Valley district lies at the junction of the Book Cliffs and the Wasatch Plateau. The coal-bearing strata are continuously exposed in the Book Cliffs from Castlegate eastward into Colorado. They crop out also in the eastern escarpment of the Wasatch Plateau from the same locality southward for more than 60 miles into eastern Sevier County, where the coal field is interrupted by the igneous mass of Mount Hilgard.

The coal exposures in Pleasant Valley are an inlier in a local swell of the strata at the junction of the Book Cliffs and Wasatch plateaus.

The main line of the Rio Grande Western Railway crosses the coal-bearing rocks at Castlegate, just east of the Pleasant Valley district, and a branch connects the coal mines in Pleasant Valley with the main line at Colton.

TOPOGRAPHY.

The surface of the Pleasant Valley region exhibits three distinct types of topography. The most prominent of these is the bare and rugged escarpments of the Book Cliffs and Wasatch Plateau, 1,000 to 1,500 feet high. That of the Book Cliffs is continuous westward from Colorado and joins the scarp of the Wasatch Plateau 12 miles west of Castlegate. It faces toward the south. The scarp of the Wasatch Plateau faces eastward and stretches to the south for 65 to 75 miles, coming to an end in eastern Sevier County. The coal measures crop out in the middle slopes of the Book Cliffs and Wasatch escarpments and in the sides of Pleasant Valley.

At the base of the Book Cliffs and Wasatch escarpments is a broad, rolling plain, open toward the south and east, known as Castle Valley, which lies 500 to 1,000 feet below the coal-bearing strata.

The third important topographic feature in this coal district is found above the outcrop of the coal-bearing rocks, the top of which usually lies a few hundred feet below the higher cliffs in the escarpments. Back of these cliffs the surface is comparatively smooth to the top of the plateau. The crests of the ridges in the general plateau level are oval and undulating, and the upper courses of the valleys are shallow and smooth except where the divides approach the escarpment. In such places the surfaces are steep and in places bluffy.

South of Pleasant Valley Huntington River has cut a deep gorge or boxlike canyon through the harder rocks associated with the coal and is now flowing on the soft shale of the underlying formation. The undercutting in the softer shale is responsible in a large measure for the precipitous character of the canyon walls. At the upper limit of the coal rocks the topography of Huntington Canyon changes from the abrupt, angular features of the box canyon to the oval though

steep slopes of the higher parts of the Wasatch Plateau. Farther north, in T. 13 S., R. 6 E., the valley is comparatively shallow, wide, and smooth.

Similar topographic conditions prevail in Pleasant Valley, which is drained by West Fork of Price River. The valley is a deep, narrow gorge near its head, but grows gradually broader and flatter toward the north, and midway between Clear Creek and Scofield the bottom is flat. It broadens northward to a width of about 1 mile at Scofield. In T. 12 S., R. 7 E., it is a flat swampy plain and has a width of nearly 2 miles. In sec. 9 the river turns abruptly eastward, leaving the swampy plain, and enters a narrow, sharp gorge, and so continues to Colton.

The hills and ridges rise gradually from Pleasant Valley in both directions. On the east the surface attains an elevation of about 1,000 feet above the valley, and on the west the slopes rise steeply to the same elevation and then more gradually to the crest of the divide between Pleasant Valley and Huntington Canyon. The altitude of this divide opposite Clear Creek is nearly 1,500 feet above the level of the valley and about 10,000 feet above the sea.

In this district, as well as throughout the coal field generally, the steeper and more barren slopes almost invariably are those that face toward the south and east. The prevailing winds are westerly, and the surfaces that face toward the west and north receive heavy falls of rain and snow. The surfaces that face southward receive the sun's rays more directly and consequently they are the more arid and are only slightly protected by soil and vegetation, forming in many places impassable cliffs hundreds of feet in height.

STRATIGRAPHY.

The coal beds of the Pleasant Valley district occur in a formation or group of strata consisting of sandstone and shale. The sandstone beds range in composition from almost pure white stone of moderate hardness to yellowish or brown argillaceous or shaly sandstone. Less is known of the composition and physical properties of the shale, for as a rule it crops out on slopes and is generally concealed by soil and talus. It ranges from clay shale to various grades of sandy shale. In the unweathered state these beds are blue to black in color and are moderately soft. In proximity to the coal beds, usually immediately above, and at some other places where coal does not occur, the shale is carbonaceous. Except where active erosion is going on there is everywhere a mantle of clay and partially decomposed strata.

In the group of strata that contains the coal beds the volume of sandstone and shale is approximately equal, and the individual beds of each range from thin layers to strata that are as much as 100 feet thick. Just below the coal bed that is mined at Castlegate, in the

lower part of the coal-bearing strata, there is a sandstone nearly 100 feet thick. The upper part is massive and light colored, but 50 to 80 feet below the top the bedding is more distinct, and farther down it grades into shaly sandstone, which is followed below by shale. A similar sandstone lies 150 to 180 feet below the Castlegate coal horizon. The upper part is massive and white to buff colored. From the middle downward the sandstone becomes more argillaceous and distinctly stratified, grading down to shaly sandstone.

The coal-bearing strata, 600 to 800 feet thick, are overlain by light-buff sandstone that contains only here and there a stratum of shale. This sandstone is several hundred feet thick. It makes imposing cliffs above the town of Castlegate, in the Price River canyon, and at many places elsewhere in the upper part of the Book Cliffs and Wasatch Plateau escarpments. Still higher stratigraphically, sandstone and shale beds succeed each other until the whole group attains a thickness of nearly 2,000 feet.

This group of sandstone and shale beds, including the coals, has been correlated with the Mesaverde formation of the Cretaceous. Fossils are not abundant and collections have not been obtained from the basal member of the sandstone and shale group.

No unconformity is apparent in the Mesaverde except in places where it is overlain by Eocene rocks.

Lying below the sandstones, shales, and coals, which are of Mesaverde age, is a great formation of blue clay shale or marl that contains large lenticular bodies of sandstone in the upper part. This shale makes the lower parts of the Book Cliffs and Wasatch Plateau escarpments and the broad, rolling plain of Castle Valley and Price River. Near the base of the cliffs and for several miles out into the plain this shale has in recent geologic time been covered by an overwash of bowlders, gravel, and sand from the plateau. This bowlder and gravel mantle was spread upon gently inclined surfaces and has been cut through to depths of 100 to 200 feet by more recent erosion, producing rough badlands surfaces.

The thickness of this shale is estimated to be not less than 1,500 feet in the Castle Valley region. The formation is tilted at a low angle toward the Book Cliffs and Wasatch Plateau and the outcrop is 15 to 18 miles in width. It includes the whole of the Colorado group and part of the Montana group and is correlated with the Mancos shale of southwestern Colorado.

The surface features of the plain above mentioned have an economic bearing on the availability of the coal. The valleys and gulches in the shale extend out from the coal areas across the edge of the plain, so that it is impracticable to build transportation lines parallel with the boundaries of the field within several miles of the coal land. It will be necessary, therefore, to build branch lines up to

the coal land from Price River or Castle Valley, as has been done from Mounds, on the main line of the Rio Grande Western Railway, to the Sunnyside mines.

STRUCTURE.

The Pleasant Valley district is on the northwestward-pitching axis of a broad, flat fold, the San Rafael Swell. The rocks dip at angles of 5° to 7° toward the north and northeast in the Book Cliffs region, east of the Pleasant Valley district, and at lower angles toward the west in the Wasatch Plateau. The Pleasant Valley district, therefore, is in the angle between the areas of northward and westward dipping rocks and is a region of local warping and low doming of the strata. In addition the strata are broken by faults of the normal or tension type. Many of these faults were located and measured in the escarpments and canyons. In the plateau regions and in the shale plain bounding the coal land below there are doubtless many other and smaller faults that were not recognized because of the obscure exposures of the rocks.

PLEASANT VALLEY ANTICLINE.

In the region of Pleasant Valley near the north end of the Wasatch Plateau the coal measures and associated rocks have been folded into a low domelike uplift or anticline. The fold is faulted and unsymmetrical, and its axis is not very clearly defined. It trends, however, generally north and south and crosses the west end of Carbon County, its northern part being coincident with Pleasant Valley. It is intersected along its axis by a large fault and the variability of the throw accounts in part for the warping of the fold.

The tilt of the rocks on the east side of the Pleasant Valley anticline is very slight, not exceeding 1° to 2°. In places along the head branches of Gordon Creek, in T. 14 S., R. 7 E., the rocks seem to be horizontal. On the upper course of North Fork of Gordon Creek, in T. 13 S., Rs. 7 and 8 E., the dip is 1° to 2° E. On the west limb of the fold near Scofield the dip is about 3° NW. From Scofield southward the direction of dip changes gradually from northwest to west and then to southwest. Between the head of Pleasant Valley and Huntington Canyon the rocks are inclined toward the southwest at an angle averaging nearly 4°.

The rocks in Huntington Canyon area slope toward the south. The dip decreases gradually down the canyon until at the mouth, in T. 17 S., the beds become almost horizontal. The outcrop of the coal-bearing rocks is at the level of the canyon floor in the eastern part of T. 14 S., R. 6 E. The grade of the river southward is but little greater than the dip of the rocks. West of the Pleasant Valley fault, in T. 16 S., R. 7 E., the lowest coal has an elevation of nearly

400 feet above the river. Just east of the fault the same rocks have been dropped down to about 200 feet above the river. They rise steplike in a series of narrow fault blocks east of the Pleasant Valley fault, in the southeastern part of T. 16 S., R. 7 E.

The lowest coal bed is probably not less than 800 feet above the river at the mouth of the canyon and above Castle Valley between Huntington and Cottonwood canyons, at the south end of the area shown on the map.

FAULTS.

The rocks of the Pleasant Valley district have been broken by two groups of normal faults of considerable displacement. These faults trend in a general north-south direction. One group extends longitudinally through Pleasant Valley and southward across Huntington Canyon. It follows in a measure the axial trend of the Pleasant Valley anticline and may be described as the Pleasant Valley fault group. The other group of faults corresponds to the walls of Joes Valley, in the southwestern part of the district, and will be known as the Joes Valley faults.

PLEASANT VALLEY FAULTS.

The principal fault of the Pleasant Valley group is the westernmost one. It follows the west side of the valley in an almost due south course, crossing the foothills and spurs near the stream and passing through the west sides of Scofield and Clear Creek. North of Scofield it lies in a swampy valley and is not traceable. Whether there is a series of fractures or a single fault is not determinable. The amount of throw or displacement is seen by the discordance in elevation of the same rock beds in opposite sides of the valley. Certain accumulations of metamorphosed sandstone in different places in the valley north of Scofield suggest that there is more than one fault. The downthrow of the rocks due to this fault is toward the east and varies in amount from place to place. The greatest displacement is near the center of the Pleasant Valley uplift.

Near the head of the valley opposite Clear Creek the throw is nearly 1,000 feet. The coal bed mined at the level of the canyon floor at Clear Creek outcrops near the top of the canyon wall 1,000 feet higher and 1 to 2 miles farther west. The outcrop of these beds descends northward to a point within a few hundred feet of the valley level west of Scofield, showing a decrease in throw of more than 500 feet in a distance of 6 miles. At the same rate of decrease the fault would almost disappear at the north end of the Pleasant Valley district.

From the head of Pleasant Valley the fault veers slightly east of south, but it has not been located in the unsurveyed part of T. 14 S.,

R. 7 E. The fault crosses Nuc Woodward Canyon in the north-central part of T. 15 S., R. 7 E., where it is distinctly traceable. The plane of fracture is almost vertical, but hades to the east, and the downthrow is in the same direction and amounts to 500 feet. The lowest coal bed, which outcrops high in the canyon wall on the west, is down at the base on the east side of the fault. The same fault crosses Tie Fork Canyon at the northern boundary and Huntington Canyon near the center of T. 16 S., R. 7 E.

On Tie Fork the hade of the fault is almost vertical, and the downthrow on the east is 350 to 400 feet. In Nuc Woodward and Tie canyons the fault bears about S. 5° E., but south of Tie Fork it curves westward, crossing Huntington Canyon with a bearing S. 5° W. The downthrow here and in North Fork of Meetinghouse Canyon is nearly 300 feet to the east. In South Fork of Meetinghouse Canyon, however, the throw is little more than 100 feet. Farther south, at some point in T. 17 S., R. 7 E., the fault dies out. The accurate location of this fault in the high land between Pleasant Valley and Huntington Canyon is important, as it has a decided bearing on the question of minable coal lands.

The other faults of the Pleasant Valley group are shorter and the vertical displacements are less. At present they are known in two localities, Pleasant Valley and Huntington Canyon. In Pleasant Valley faults of small extent occur in the vicinity of the Clear Creek and Winterquarters mines. One is nearly half a mile east of Clear Creek and trends slightly west of south. The direction and amount of throw was not determined. The throw is certainly not very great, or else there are other faults on the east and near at hand with opposite and compensating displacement. The outcrops of the coal at Clear Creek and on the headwaters of Gordon Creek to the east are at nearly the same level. Local faults are present south of Winterquarters, but they trend in an east-west direction and the displacements are less than 100 feet. Other faults of minor extent and throw probably occur in the vicinity of Pleasant Valley and at other places in the higher parts of the district and have escaped detection because of the soil cover and smooth surface features.

A number of faults cross Huntington Canyon within 2 miles east of the Pleasant Valley fault and nearly parallel to it. Their locations are indicated on the map (Pl. XX, p. 338). They vary in throw from a few feet to nearly 250 feet, and in all of them the downthrow is toward the west. The total downthrow of these faults almost exactly compensates for the eastward downthrow of the Pleasant Valley fault. The minor faults almost surely do not extend more than 12 miles either northward or southward, for they are not visible in the escarpments along Gordon Creek on the north and Cottonwood Creek on the south. As usual, the planes of faulting are nearly vertical or slightly inclined toward the downthrow. The fault

nearest the Pleasant Valley fault in Tie Canyon has a downthrow to the west of 100 to 150 feet; the other, near the east line of sec. 3, has a downthrow to the west of 200 to 250 feet. These two faults have a combined displacement approximately equal to all those showing in Huntington Canyon east of the Pleasant Valley fault. Where the faulting is less pronounced the rocks on either side are, as a rule, distinctly jointed in planes parallel to the fault line. It appears that the faults die out in a series of joints, some of which are miniature faults. Away from the faults and even near the larger ones the jointing of the rocks is not pronounced.

JOES VALLEY FAULTS.

Less is known of the faults in the Joes Valley region than of those in Pleasant Valley. They are farther back on the plateau, where rock exposures are less distinct and where minor faults are not easily detected.

A group of these faults, one of which has a pronounced displacement, bears a few degrees west of south through the western part of the area represented by the map. The easternmost one has been precisely located in Huntington Canyon in sec. 14, T. 14 S., R. 6 E.; in West Fork of Huntington Canyon, sec. 11, T. 15 S., R. 6 E.; in Joes Valley, sec. 22, T. 16 S., R. 6 E.; and in sec. 32, T. 17 S., R. 6 E. Between these localities the fault was located approximately by reconnaissance. South of Huntington Canyon the fault is distinctly marked by a well-defined scarp several hundred feet high, which faces toward the west. This fault scarp is especially prominent along the east side of Joes Valley, across Tps. 16 and 17 S., R. 6. E., and farther south. The downthrow of the fault is toward the west and amounts to probably not less than 1,000 feet.

The west side of Joes Valley near the border of the area mapped is bounded by a bluff closely resembling the fault scarp on the east side. The horizontal rocks exposed here also appear to be the same as the Mesaverde beds that occur on the east side of the Joes Valley fault. If this interpretation is correct there is a fault on the west side of the valley, the downthrow of which is toward the east and amounts to nearly the same as the displacement of the fault on the east side. At the southern boundary of T. 17 S., R. 6 E., the stream draining Joes Valley turns abruptly eastward and enters the deep and narrow gorge called Straight Canyon. Notwithstanding this change of the stream course, the broad flat valley with the fault scarps on either side continues toward the south, in line with Joes Valley, across the divide to Ferron Canyon, where both faults are distinctly shown. The downthrown fault block is here 2 miles in width. The throw of the eastern fault is 300 feet; that of the western is probably three times as great.

Ferron Canyon is a deep gorge and the coal is exposed in its walls west of the fault block. It is probable also that the coal is available by shaft in Straight Canyon west of the fault and near the southwest corner of T. 17 S., R. 6 E. In general the coal within and west of the fault block is probably not available except in the deeper valleys.

FAULTS EAST OF PLEASANT VALLEY.

Near the headwaters of North Fork of Gordon Creek, in the Book Cliffs escarpment, there are a number of small faults which vary in trend from nearly north and south to northwest and southeast. Two of these faults that bear a few degrees east of north are located near the head of Spring Canyon, in sec. 10, T. 13 S., R. 8 E. The downthrow of each is toward the other, and the displacement of the easterly fault is 150 to 200 feet. The throw of the other is not so easily determinable, but it seems to be somewhat less. These faults are traceable northward into the SE. ¼ sec. 3. Two faults, corresponding in strike and in direction of throw to those just described, were noted at the crest of the ridge in the N. ½ sec. 15. Thence they bear a few degrees east of south. The block between the faults is thrown down about 100 feet.

A fault bearing nearly due north and having a throw of 150 feet toward the west crosses the outcrop of the coal-bearing rocks in the E. ½ sec. 16. Another was noted in the NE. ¼ sec. 16 and the SW. ¼ sec. 9. This bears N. 12° W., and the throw is small toward the east.

Two faults were located in the gulch near the southeast corner of sec. 16. The one with more northerly bearing has a displacement of 50 feet in the NW. ¼ sec. 21. Farther north, near the west line of sec. 16, it changes to a monoclinal fold. The other fault bears N. 65° W. and has a downthrow of 20 feet to the southwest. Another fault crosses the NE. ¼ sec. 20, bearing N. 50° W. with a downthrow of 50 feet to the southwest. Another, with nearly the same bearing, crosses the canyon near the center of the NE. ¼ sec. 19, with a throw to the northeast of 75 feet. Another fault, bearing due north, crosses the same canyon near the west line of sec. 19. Its downthrow is 50 feet toward the west. Two other small faults were noted in the unsurveyed part of T. 13 S., R. 7 E., near the head of North Fork of Gordon Creek. The downthrow of each is toward the other and ranges from 30 to 50 feet, resulting in a narrow downthrown block.

All these faults are of the normal type, and the planes of fracture are nearly vertical where exposures permit examination. The smaller faults can not be traced, except where erosion has exposed the edges of the rock beds.

COAL.

Coal has been prospected and mined at three localities in the Pleasant Valley district. These are in or near Pleasant Valley, in or near the Price River canyon in the vicinity of Castlegate, and in or near Huntington Canyon, in the northwestern, northeastern, and southern parts of the district, respectively. They could be easily reached by lines of transportation, and in the near future railroads may be constructed to them.

PLEASANT VALLEY.

Prospecting for coal in Pleasant Valley has not been thorough or extensive, except in the vicinity of the Clear Creek, Winterquarters, and Scofield mines. The outcrop of the coal-bearing rocks extends not only from Clear Creek, near the head of Pleasant Valley, to Scofield, but through the borders of the valley down West Fork of Price River almost to the east border of T. 12 S., R. 7 E. Along the east side of the valley the coal outcrops near the level of the streams from the mines at Clear Creek northward to Scofield. Its presence is attested by a number of prospects along the outcrop and by the mines at Clear Creek and Scofield. The pitch of the coal toward the north is but little greater than the grade of the valley, and continues at approximately the same angle down the east side of the valley through T. 12 S., R. 7 E. The same coal-bearing beds outcrop at higher elevations on the west side of Pleasant Valley from its head, in T. 14 S., R. 7 E., to Fish Creek, in T. 12 S., R. 7 E. The difference in elevation of the coal on opposite sides of the valley is caused by the fault that trends with the valley, following the west side of the stream. Opposite Clear Creek the coals on the west side are nearly a thousand feet above the valley floor. The northward inclination of the coal beds is greater on the west than on the east side of the valley. In secs. 30 and 31, T. 12 S., R. 7 E., the lowest coal bed mined is scarcely 200 feet above the plain of Pleasant Valley. Near the northeast corner of sec. 19, T. 12 S., R. 7 E., the same beds descend to the valley floor and toward the north pass beneath the surface. The presence of coal on the west side of the valley is attested by many prospects and the Winterquarters mine, as well as by certain prominent and characteristic sandstone beds that are associated with the beds of coal. These sandstone beds are not exposed continuously, but they can be seen here and there, and the coal beds lie in definite positions with respect to them. Coal-bearing rocks corresponding to those at Clear Creek occur also on the east side of the divide in slopes leading to Castle Valley, a few miles east of Clear Creek, and on the west in Huntington Canyon, in the northeastern part of T. 14 S., R. 6 E.

At least four coal beds of workable thickness and of commercial quality are known in Pleasant Valley, and they occur in succession one above another through about 600 feet of rocks. These coal beds may be separated into two groups. The first comprises two beds, in places three, that lie in the lower part of the coal-bearing section. These are the thickest and most accessible beds, and in consequence are the ones most extensively developed. They are mined at Clear Creek and Winterquarters and have been mined at Scofield. Coal beds in the same group have been prospected on the west side of the valley opposite Clear Creek, between Clear Creek and Scofield, and north of Winterquarters, in secs. 19, 30, and 31, T. 12 S., R. 7 E.

The coal that is mined at Clear Creek crops out at the base of the valley near the center of the W. ½ sec. 33, T. 13 S., R. 7 E. It has been mined eastward into the mountain a distance of nearly one-half mile and in a north-south direction for more than 7,000 feet. The coal bed varies in thickness from north to south. In the southern part of the mine it is 13 feet 5 inches thick. Near the center of the workings a thin shale parting enters the coal. Toward the north, within a distance of 2,000 feet, the shale swells to 16 feet, dividing the coal bed into two benches. Where the shale is thick, only the upper bench of 4 feet 6 inches of coal is worked.

A coal bed at the same geologic horizon as that mined at Clear Creek and another bed 100 feet higher have been prospected in not less than fifteen localities in sec. 31, T. 13 S., R. 7 E. In most places the earth has fallen into the pits, partially concealing the coal. In the SW. ¼ NE. ¼ sec. 31 a prospect on the lower bed shows 11 feet of coal, the base and the top being concealed. In the SE. ¼ NW. ¼ sec. 31, 6 to 8 feet of coal are exposed. Water in the pit prevented further examination of the bed. A prospect on the second bed 100 feet above the first, located in the SW. ¼ NW. ¼ sec. 31, exposes 15 feet of coal. The same bed has been exposed in the NE. ¼ SW. ¼ sec. 31, showing 17 feet of massive coal. In the south half of the same section two coal beds 25 feet apart have been prospected. A partial exposure of one shows 5 feet and of the other 10 feet of clean coal.

Near the center of the east side of T. 13 S., R. 6 E., the bed that is mined at Winterquarters and Clear Creek, or one near the same stratigraphic position, is mined, and the coal is hauled to Scofield. The bed has a clear section of coal 12 feet thick. Mining was begun here on the north side of the canyon by a slope, but this was abandoned, and an entry has been driven on the rise of the bed toward the south.

One of the beds near the base of the coal-bearing section has been mined for a number of years at Winterquarters, and this mine is now

in active operation. The workings are at present toward the south on the rise of the bed. The same bed has been worked northward into the N. ½ sec. 31, T. 12 S., R. 7 E. The coal in the mine at present worked is 9 to 16 feet thick and has no partings.

A number of prospects have been made and an entry opened from the Scofield mine in a gulch in the N. ½ sec. 31, T. 12 S., R. 7 E., but the coal bed is not now exposed. One prospect in the SE. ¼ NW. ¼ sec. 31 shows 4 feet 9 inches of coal between beds of sandstone. In the NW. ¼ SE. ¼ sec. 35 the coal is 5 feet 10 inches clear.

One of the lower workable beds was formerly mined at the southeast side of Scofield by the Union Pacific Company, but the plant is abandoned and in charge of a keeper. The bed is reported to be about 30 feet thick, but the middle portion only was worked, because of the great thickness and for the reason that coal forms a better roof and floor than the country rocks. South of the main entry of the old working a cave-in has occurred in a small gulch, exposing two overlying workable beds. The upper of these beds is 9 feet thick, the lower is 5 feet 3 inches, and the two are separated by 5 feet of shale and thin sandstone beds. The proximity of these coal beds to the lower and thicker one that has been mined will depreciate their value unless the higher beds are mined first, which is not likely to occur.

One, probably two, workable coal beds occur above the coal that has been mined at Clear Creek, Winterquarters, and Scofield. The first of these is nearly 200 feet above the Clear Creek bed, and it has been opened in two prospects one-fourth to one-half mile southeast of Clear Creek. The coal in the southern of these prospects is exposed for 5 feet 3 inches in a shallow pit. The relations of the contact rocks are not clear on account of the deep covering of soil. The indications are that the coal is of fair quality.

Another coal bed, estimated to be 500 feet above the Winterquarters bed, has been prospected at a number of places in secs. 10, 11, 13, and 14, T. 12 S., R. 7 E., near the railroad in Pleasant Valley Canyon. This bed, as shown in prospect pits in secs. 10, 11, and 13, ranges in thickness between 3 feet 6 inches and 3 feet 7 inches. The roof is usually shale and the floor sandstone. Locally the shale thins out and sandstone comes into contact with the coal. The bed has been mined in sec. 14, but the entry is now closed by fallen earth. The coal is clear and mines in small blocks, with the production of considerable slack.

What appears to be the same bed is being mined by Mr. Metcalf on unsurveyed land in the northeastern part of T. 12 S., R. 6 E., near the location of sec. 2, in the canyon of North Fork of Fish Creek. The coal has the same thickness and similar contact relations as the bed in the prospects in Pleasant Valley Canyon. This

coal is regarded as a good fuel and is utilized in the neighborhood and hauled to Utah County for domestic use.

A coal lying at nearly the same stratigraphic position, if it is not the same bed as the Clear Creek coal, has been mined at intervals for a number of years in Huntington Canyon 4 miles southwest of Clear Creek and hauled into Sanpete County for domestic use. A number of entries have been run eastward from the outcrop of the coal on the east side of the gulch and abandoned for new entries when it became more economical to work nearer the surface. The miners report that the coal is clear of shale and that the thickness ranges from 9 to 11 feet. The same coal bed or one near the same geologic position is being mined for local use by the Larsen Brothers on West Fork of Huntington Canyon, in sec. 2, T. 15 S., R. 6 E. The coal is 8 feet thick and lies between beds of sandstone.

PRICE RIVER.

Thick sandstone beds crop out just below and in association with the principal coal beds in the Price River canyon below Castlegate, as elsewhere in the Book Cliffs region. These beds form almost continuous cliffs and the outcrops of the coal beds can be traced accurately by reference to them. The principal coal beds lie almost directly upon certain thick sandstones that have characteristically light-buff layers or borders at the top. These peculiar features are known to the prospectors and are guides to the most economical prospecting of the coal.

Extensive prospecting has been done on the coals, chiefly in the lower part of the coal-bearing rocks, in T. 13 S., Rs. 9 and 10 E., and mining is actively carried on at Castlegate. Some prospecting has been done on North Fork of Gordon Creek in T. 13 S., R. 8 E.

In Helper Canyon, east of Price River, four workable beds are opened in prospect pits. The section including these coals is as follows:

Section of coal beds in Helper Canyon.

	Ft.	In.
Shale.		
Coal, with thin bony layer 1 foot 6 inches below top	4	
Shale and thin sandstone / Shale	110	
Coal	7	
Sandstone / Shale	120	
Coal, with bony shale 2 to 3 inches at center	5	10
Shale and shaly sandstone / Shale	40	
Coal, with thin shale parting near center	10–11	
Shale	12	
Coal	1	
Sandstone	80–100	

The three lowest coal beds are exposed on the west side of Bull Canyon in sec. 16, T. 13 S., R. 10 E.

Section of coal beds in Bull Canyon.

	Ft.	in.
Shale, weathered.		
Coal, decomposed	3	
Coal	10	
Shale	1	
Coal	2	4
Sandstone, massive	60	
Coal	8	
Shale and thin sandstone	50	
Coal	18	
Sandstone, massive	80	
	232	4

The lowest coal, 18 feet thick, has no shale parting. This bed is 20 feet clear in sec. 10, in Cordingly Canyon, where it is mined and hauled to Price for domestic fuel. Its quality for this purpose is reported excellent.

The lowest workable bed has been prospected at a number of places on the west side of Helper Canyon and in Panther Canyon, in secs. 7 and 8, T. 13 S., R. 10 E. In the SE. ¼ sec. 7 the bed is 9 feet thick and clear of shale. In the NE. ¼ sec. 7 it is 10 feet 8 inches thick and of equally good quality.

The lowest workable bed thus far noted in this vicinity is mined at Castlegate. The mine extends southwestward on the rise of the coal bed from Price Canyon. The bed is somewhat variable in thickness, increasing toward the south from about 4 to 10 feet. Sandstone is usually in contact with the coal both above and below, but locally shale lies between the sandstone and coal.

West of the Price River canyon one, in places two, workable coal beds come in below the Castlegate coal and below the lowest known coal east of Price River. The following is a section of the coal and associated rocks in secs. 3 and 10, T. 13 S., R. 9 E. The thicknesses of rock between the coal beds were determined by barometer readings and are only approximately correct.

Section on west side of Price Canyon.

	Ft.	in.
Sandstone.		
Coal	1	8
Shale	4	
Sandstone and shale	60	
Coal	2	
Interval	20	
Shale and thin coal	4	
Coal	5	
Shale and bony coal; Sandstone and shale; Shale	80	

	Ft.	in.
Coal	3	3
Sandstone and shale	15	
Shale	1	6
Coal (Castlegate)	5	10
Sandstone, massive, grading downward into shale	100	
Slope, chiefly shale	75	
Coal	6	
Sandstone, lower part shaly	200	
	583	3

The following section of the lower coal beds and intervening rocks was noted in a gulch leading to Spring Canyon in sec. 9, T. 13 S., R. 9 E.

Section in Spring Canyon.

	Ft.	in.
Shale.		
Coal (Castlegate), part exposed	9	4
Concealed	1	
Sandstone, massive, about	100	
Sandstone and shale, slope	33	
Sandstone	40	
Shale	2	
Coal	5	
Shale and thin sandstone	16	
Shale, bituminous, and thin coal	9	
Coal	5	
Sandstone, massive, buff.		
	220	4

The Castlegate coal, on the north side of Spring Canyon, near the center of sec. 8, is 15 feet thick. The coal is massive, has a shale roof, and is underlain by 150 feet of sandstone.

The same coal or a bed near the same stratigraphic position has been prospected in Spring Canyon near the northeast corner of sec. 12, T. 13 S., R. 8 E. Ten feet of massive coal in the central part of the bed are exposed. Decomposed rock conceals the roof and top of the bed and concealed strata lie between the coal and the sandstone cliff below.

The Castlegate coal is 7 feet thick on North Fork of Gordon Creek, in the SW. ¼ SW. ¼ sec. 16, T. 13 S., R. 8 E. The roof is shale and a thin shale lies between the coal and the massive sandstone below.

In the NE. ¼ sec. 20, of the same township, two coal beds are exposed 175 and 200 feet below the Castlegate horizon. The upper of these is 6 feet 6 inches thick and has bony layers 1 inch thick 2 feet below the top. The other bed is 13 feet thick, with a thin shale parting 3 feet below the top.

One of these beds is exposed in the SE. ¼ sec. 7, showing 7 feet 6 inches of coal with a 1-inch parting of bone 2 feet below the top.

The same bed in the NE. ¼ sec. 19 is 7 feet thick and has the same bony streak 2 feet below the top.

The coal-bearing rocks near the headwaters of Gordon Creek, in Tps. 13, 14, and 15 S., R. 7 E., and T. 15 S., R. 8 E., are not well exposed, and little or no prospecting has been done. A coal bed at or near the horizon of the Castlegate coal is exposed on a spur at the head of Bob Wright Canyon in unsectioned land, 6 to 7 feet of weathered coal being visible. The same bed shows 6 to 8 feet of coal in the location of the unsurveyed NW. ¼ SW. ¼ sec. 14, T. 14 S., R. 7 E. As usual, it occurs just above the massive sandstone and appears to have a shale roof.

HUNTINGTON CANYON.

From the northern part of T. 15 S., R. 8 E., southward through and beyond Huntington Canyon the coal-bearing rocks crop out in barren cliffs, as in the Book Cliffs region. In Miller, Cedar, and Huntington canyons the coals are naturally exposed in many places, and considerable prospecting and some mining has been done. The coal beds occur in the same group of rocks as the coal beds in the vicinity of Castlegate. Whether or not any bed is continuous from one area to the other can not be determined until mining or drilling is done in the intermediate region. The two lower beds, however, overlie the same sandstone formation as the two lower beds on the west side of Price Canyon, and a higher bed occurs in the same relative position as the Castlegate coal.

Natural outcrops of the lower beds occur in many places in secs. 21 and 22, T. 15 S., R. 8 E. The full thickness of the beds is rarely exposed in these natural outcrops. The lowest bed in the SW. ¼ NE. ¼ sec. 21 shows 11 feet of clear coal. In the southeast quarter of this section the exposure shows 9 feet of coal. The bed is overlain by sandstone, and light-blue clay a few feet thick usually occurs between the coal and the sandstone cliff below. The same bed has an exposure of 10 feet in an old prospect in the SW. ¼ NW. ¼ SE. ¼ sec. 17, T. 15 S., R. 8 E.

An old prospect on a bed at the Castlegate horizon a short distance north of the center of the E. ½ sec. 19 shows 6½ feet of coal, the bed being partially concealed.

The lowest coal bed shows in prospects on Middle Fork of Miller Creek, in the NW. ¼ SE. ¼ NW. ¼ sec. 29. A partial exposure of the bed gives 9 feet of clear coal. The Castlegate bed is prospected in the NE. ¼ SE. ¼ NE. ¼ sec. 30, showing 6 feet of coal, with a thin parting of bone 6 inches below the top.

The two lower beds have been mined for local use in the NE. ¼ NW. ¼ sec. 32, T. 15 S., R. 8 E., the upper one being 5 feet and the lower 10 feet 6 inches thick; both are clear coal. The lower coal

and also the coal at the Castlegate horizon show on the north side of Cedar Canyon, in secs. 3 and 9, T. 16 S., R. 8 E. Only partial sections of about 10 feet each could be seen.

The lowest coal has been mined for a number of years in Cedar Canyon on the line between secs. 8 and 9 to supply domestic fuel for Huntington. The coal bed is about 20 feet thick and contains a few very thin, variable, bony streaks. The same bed near the center of the north side of sec. 9 is 12 feet 6 inches thick. Shale and shaly sandstone overlie the coal on Cedar Creek and massive sandstone nearly 100 feet thick occurs immediately below.

A single natural outcrop exposing 6 feet of coal was noted in Fish Canyon near the north side of the NE. ¼ SW. ¼ sec. 20.

Much prospecting has been done, chiefly on the lower coal beds, in Huntington Canyon in T. 16 S., R. 7 E., and in the northeastern part of T. 17 S., R. 7 E. In Bear Canyon, in the SE. ¼ sec. 24, T. 16 S., R. 7 E., four workable beds of coal have been opened. A section of these coals and associated rocks is as follows:

Section of coal in Bear Gulch.

	Ft.	in.
Coal	6	6
Shale and thin coal, interstratified	6	
Sandstone	20	
Coal	1	6
Sandstone, shaly sandstone, and shale	150	
Shale	3	
Coal	7	
Sandstone	30	
Coal, variable in 200-foot entry	8	11
Sandstone, shaly at top	120	
Coal	4-5	
Sandstone cliff	85	
	442	11

Entries have been driven on two coal beds near the southeast corner of sec. 24. The upper bed ranges from 10½ to 15 feet in thickness in an entry 300 feet long. The coal has a shale roof and is separated from the lower bed by 50 feet of sandstone. The lower coal bed is 6 feet 6 inches thick and is inclosed by sandstone.

In Deer Creek canyon, in the NW. ¼ sec. 11, T. 17 S., R. 7 E., the lowest coal is 16 feet 6 inches thick where it has been mined for local use. A second bed has been prospected on the north side of the gulch and 4 feet of coal is exposed containing a band of bone 2 inches thick 1 foot above the base. Both these beds are prospected in South Fork of Meetinghouse Canyon, where 4 feet of the lower bed and 10 feet of the upper are exposed, divided 4 feet above the base by 6 inches of shale. In North Fork of Meetinghouse Canyon the

upper bed is 11 feet thick and the 6-inch shale parting is 3½ feet above the base. The lower bed has the following section:

Section of lower coal in North Fork of Meetinghouse Canyon.

	Ft.	In.
Sandstone, massive.		
Shale	2	
Coal	1	
Shale and sandstone	6	
Coal	1	6
Shale		6
Coal	13	6
Sandstone, massive cliff.		
	24	6

Three coal beds are exposed in Ridley Canyon near the northeast corner of sec. 28, T. 17 S., R. 7 E. The following is the section:

Section of coal beds in Ridley Canyon.

	Feet.
Sandstone.	
Coal, in part burned, exposed	8
Sandstone	30
Coal	2
Sandstone and shale	30
Coal	10
Sandstone	75
	155

Two beds are opened near the mouth of Trail Gulch. The lower is exposed between cliffs of sandstone in the NW. ¼ SW. ¼ sec. 23, T. 16 S., R. 7 E., where it is 7 feet 10 inches thick, and in the NE. ¼ NE. ¼ sec. 22, where it consists of 6 feet of clear coal. The upper bed, 60 feet higher in the section, is opened by an entry 200 feet long near the center of the east side of sec. 22. Water in the entry prevented exploration, but at the opening the bed shows 14 feet of coal from the base upward. The roof is concealed and decomposed rock covers the top of the bed. The prospector who drove the entry reports that at 100 feet from the outcrop the bed is 16 feet 4 inches thick.

The same two coals have been prospected extensively in Mill Gulch and on the west side of Huntington Canyon, in secs. 16 and 17, T. 16 S., R. 7 E. The lower bed ranges in thickness from 4 to 6 feet. An intermediate bed 3 feet 3 inches thick was located in the SE. ¼ sec. 16. Less attention has been given to prospecting the upper bed in this locality and but one full section of the coal was noted. Near the center of the east side of sec. 17 the bed is partially burned near the surface, but 3 feet in the lower part could be seen. In the SE. ¼ SW. ¼ sec. 16 this coal is 14 feet thick and lies between beds of sandstone.

The same beds are opened in Little Bear Canyon, in the NW. ¼ sec. 9. The upper bed is broken by shale partings, as shown in the following section:

Section in Little Bear Canyon, in the NW. ¼ sec. 9, T. 16 S., R. 7 E.

	Ft.	in.
Shale, bony	3	
Sandstone, shaly	4	
Coal	2	3
Shale, sandy	2	10
Coal, and shale in thin bands	1	6
Coal, lower bench of upper bed	6	
Sandstone and shale slope, with thin band of intermediate coal	50	
Coal, lower bed	5	
Sandstone, massive, in cliffs.		
	74	7

A similar section is exposed in Tie Canyon, in the NW. ¼ sec. 3, T. 16 S., R. 7 E., as follows:

Section in Tie Canyon.

	Ft.	in.
Slope, rocks concealed.		
Shale, bone, and thin coal layers	3	
Coal	1	10
Shale		8
Coal, lower bench of upper bed	3	10
Sandstone and shale beds	60	
Coal, lower bed	7	5
Sandstone, in cliffs.		
	76	9

The lowest bed is exposed in Crandalls Canyon, in the NW. ¼ sec. 5, T. 16 S., R. 7 E., with a thickness of 5 feet 6 inches.

Little prospecting has been done in Huntington Canyon in Tps. 14 and 15 S., R. 7 E. Apparently the lowest coal commonly found in this canyon in Tps. 16 and 17 S., R. 7 E., thins out farther north.

The lowest workable coal bed has been mined intermittently for a number of years at the Johnson mine, in Cottonwood Canyon, near the center of sec. 25, T. 17 S., R. 6 E. The thickness ranges from 7 feet 6 inches to 8 feet and the bed has no parting. It is overlain by shaly sandstone and has a massive sandstone floor.

The same coal bed has been worked for local use at the Reed mine, near the south side of sec. 22, and at the Otterson mine, near the east side of sec. 26, T. 17 S., R. 7 E. At the Reed mine the coal is 7 feet 6 inches thick and clear of shale. It has a variable but thin bony shale roof and lies upon sandstone. The coal at the Otterson mine is 11 feet 10 inches thick, but contains a variable thin shale parting near the middle. Shale and thin coal in alternate

layers with a total thickness of 3 feet 8 inches overlie the Otterson coal and a thin bony shale lies between it and the thick sandstone formation below.

QUALITY OF COAL.

In 1905 samples for analytical tests were collected from the principal coal beds in this district and in the Book Cliffs farther east. Proximate analyses of these samples were published in a brief report on the Book Cliffs coal field.[a] Similar samples were collected in the Pleasant Valley district during the last summer. These samples were obtained by cutting a channel across the face of the coal beds, all the partings more than three-eighths of an inch thick being rejected. The material thus obtained was crushed and quartered until a quart sample was obtained of coal that would pass through a half-inch mesh. This was sealed air-tight in a galvanized-iron can and sent to the chemical laboratory. The analyses were made at the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., by F. M. Stanton, chief chemist. They are as follows:

Proximate analyses of coal samples from the Pleasant Valley district, Utah.

	Castlegate.		Winter-quarters.	Clear Creek.	Sec. 11, T. 14 S., R. 6 E.	Sec. 24, T. 16 S., R. 7 E.	Sec. 2, T. 15 S., R. 6 E.
Laboratory No.	2098.	2097.	2541.	542.	2409.	2410.	2387.
Analysis of sample as received:							
Moisture	4.72	6.13	8.10	7.02	5.19	6.04	8.46
Volatile matter	39.13	40.07	40.21	41.89	43.80	38.96	41.17
Fixed carbon	48.45	45.45	45.91	45.80	46.91	48.40	46.09
Ash	7.70	8.35	5.78	5.29	4.01	6.60	4.28
Sulphur	.49	.56	.86	.57	.31	.83	.48
Loss of moisture on air drying	1.30	3.50	3.90	3.10	2.30	2.90	3.50
Analysis of air-dried sample:							
Moisture	3.47	2.73	4.37	4.04	2.96	3.23	5.15
Volatile matter	39.64	41.52	41.84	43.23	44.92	40.12	42.75
Fixed carbon	49.09	47.10	47.77	47.27	48.02	49.85	47.86
Ash	7.80	8.65	6.02	5.46	4.10	6.80	4.44
Sulphur	.50	.58	.89	.58	.32	.85	.50

These analyses are representative of several coal beds. They show an evenly good grade of fuel, moderately low in moisture and ash, and remarkably low in sulphur. The low percentage of sulphur seems to be characteristic of the Cretaceous coals in the Rocky Mountain region.

Coking tests have not been made of all the workable coals in this district. The beds now mined, however, have not produced merchantable coke.

The coals of the Pleasant Valley district generally contain little hygroscopic water. The coal in the thicker beds is generally massive and mines in somewhat uneven and often large blocks. Most of

[a] Contributions to Economic Geology, 1905: Bull. U. S. Geol. Survey No. 285, 1906, p. 294.

the coal has a bright luster and withstands long surface exposure without slacking. On their chemical and physical properties these coals should be classed as high-grade bituminous coal. They are regarded as an excellent domestic and steaming fuel.

DEVELOPMENT AND TRANSPORTATION.

Except for local domestic use the development of the Pleasant Valley district is limited to the Castlegate, Winterquarters, and Clear Creek mines. These mines produce annually about half a million tons, more than half the coal product of the State. A thick bed was once mined at Scofield by the Union Pacific Railroad Company, but was abandoned, it is reported, because of transportation difficulties.

The transportation of coal in this region is entirely in the control of the Rio Grande Western Railway. Castlegate is on the main line of this road and the Pleasant Valley mines are reached by a branch from Colton, near the summit of the Wasatch Plateau. The outcrops of the coal beds may be reached by roads from Castle Valley up any of the larger valleys and canyons. The coal in Huntington Canyon has a long and tortuous outcrop. The canyon is deep and has a narrow but flat floor. The grade is believed to be less than that of Price River above Castlegate. Similar conditions are to be found in Cottonwood Cayon, at the south edge of the district.

THE IRON COUNTY COAL FIELD, UTAH.

By Willis T. Lee.

INTRODUCTION.

This paper is a brief preliminary report on the occurrence and character of the coal of Iron County, southwestern Utah. During the summer of 1906 the principal coal openings were visited, the coal was sampled for analysis, and the stratigraphic position of the coal-bearing sediments was determined. No attempt, however, was made at mapping the outcrops.

The occurrence of workable coal in southwestern Utah has been known since the year 1854, when the first mine of this region was opened. The coal is located in Colob Plateau, east of Cedar City and Kanarraville, and to the west of the plateau in the eastern slope of Pine Valley Mountain near New Harmony. (See Pl. XXI.) The coal has long been of local importance, but it is so far from any large market that it has not been of great value until the construction of the San Pedro, Los Angeles and Salt Lake Railroad, which now passes within 35 miles of the principal outcrops. A branch might easily be constructed from this road to some of the most promising mines.

Little is known of the quality, the available quantity, and the accessibility of the coal. The structure of the region is such that some of the coal outcrops in the precipitous cliffs bordering the plateau, 3,000 feet or more above the plains to the west, and some of it outcrops at the bottoms of canyons and near the level of the plains. For these reasons a knowledge of the geography, the stratigraphy, and the structure of the region is necessary in order to form a proper estimate of the value of the coal lands.

SURFACE FEATURES.

The coal of Iron County outcrops mainly in the cliffs at the western margin of Colob Plateau, which has an elevation of about 9,500 feet, about 4,000 feet greater than that of the Great Basin to the west. The streams have eroded a few sharp canyons near the edge of the

plateau, the largest of which is that of Coal Creek. Although this creek, as it emerges from its canyon, is a stream of considerable size, its waters are soon absorbed by the sands and gravels of the Lake Bonneville beds of the Escalante Desert.

The ruggedness of the country in the vicinity of the coal deposits is perhaps the most serious drawback to their development. A railroad might easily be built to the foot of the Colob escarpment, but most of the coal lies near the top of the plateau, 3,000 feet or more above the base. Railroad lines are said to have been surveyed, connecting the Coal Creek and New Harmony mines with the San Pedro, Los Angeles and Salt Lake Railroad to the west, but no construction work has been done on them.

GEOLOGY.

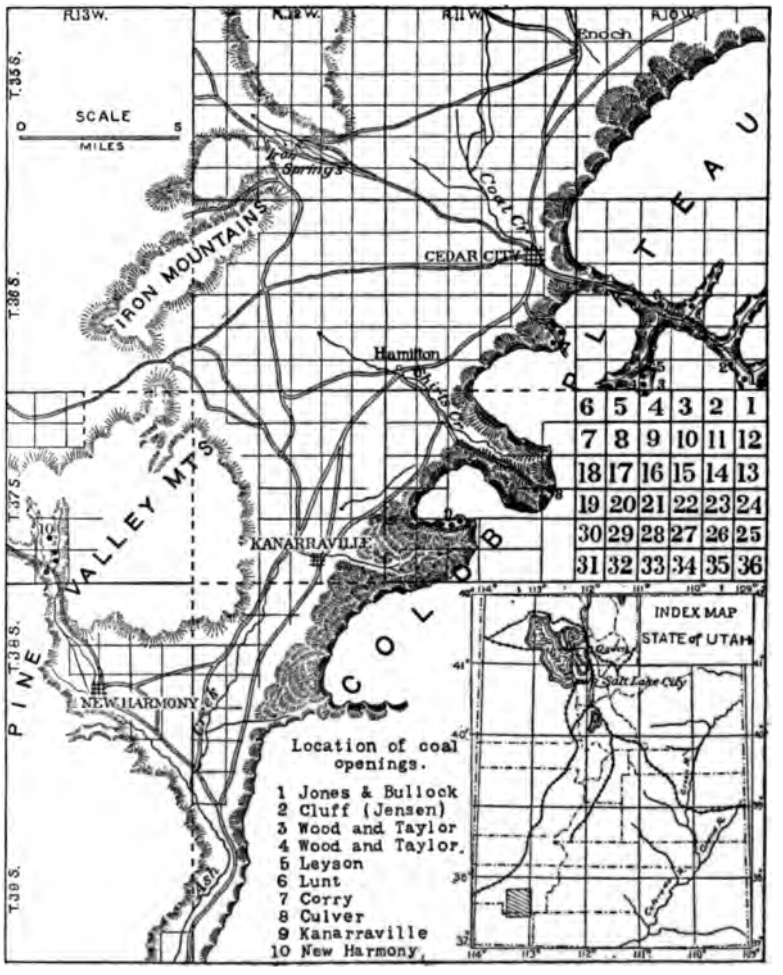
DETAILED SECTIONS.

COLOB PLATEAU.

At the coal mine 4 miles east of Kanarraville a section was measured from the coal bed to the top of the plateau. A considerable thickness of the coal-bearing formation has been eroded at this place and the plateau is covered with basalt. The part remaining, having a thickness of 463 feet, is, therefore, only the base of the formation. In the canyon of Coal Creek the remaining part was found to be 1,100 feet thick. No detailed section was obtained above the coal in this canyon, but the upper beds, so far as observed, are not notably different in composition and physical character from the lower ones, and the same species of fossils were found through the entire thickness.

The Coal Creek canyon affords exceptionally good opportunities for making detailed geologic sections. The older formations are steeply upturned near the mouth of the canyon, and the younger formations lie more nearly horizontal a few miles farther upstream. The thicknesses given in the accompanying section were obtained by barometer where the strata are horizontal and by pacing across the strike and correcting for dip where the rocks are upturned. The coal bed (Lunt mine) at the top of this part of the section (No. 9) is presumably the same as that of the Kanarraville coal and is the means by which the upper and middle parts of the section are connected.

The basal beds of the red shale and sandstone are not exposed on Coal Creek, but the lower members, together with an underlying massive limestone, are exposed near Kanarraville. About 5 miles south of this town a section was measured extending from the limestone (No. 33 of the section), which is imperfectly exposed along Coal Creek to the base of the plateau. Fossils were collected from this limestone, both in the Coal Creek canyon and south of Kanarraville, and the forms were determined by G. H. Girty to be the



MAP OF PART OF SOUTHWESTERN UTAH.

Showing coal openings.

same. On this basis the limestone is made the means of connecting the middle and lower parts of the section.

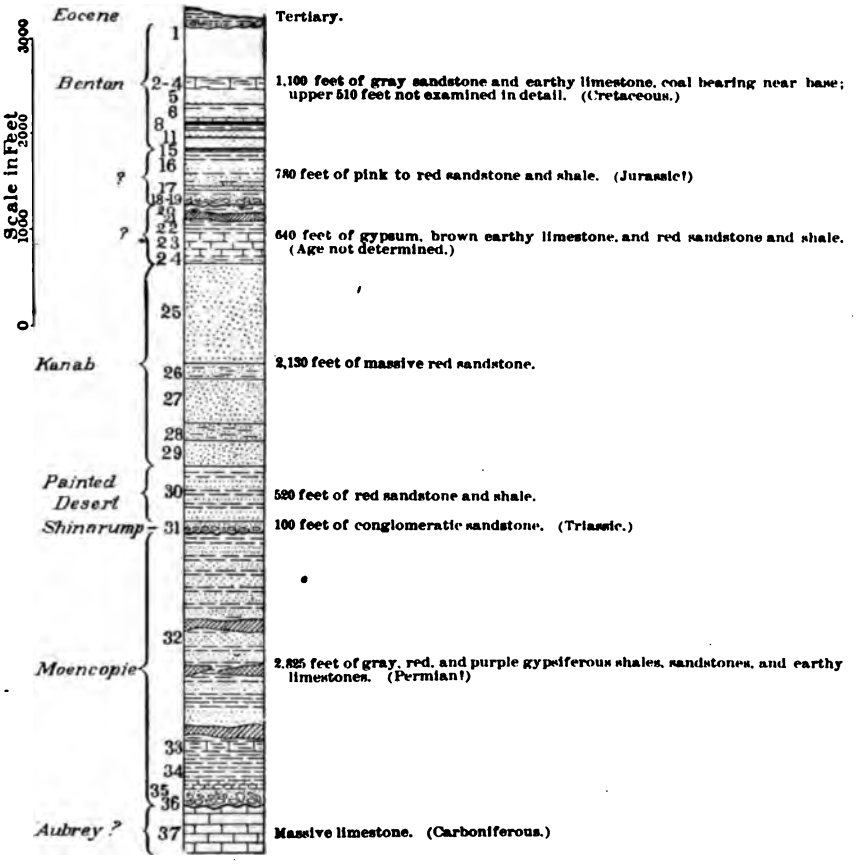


FIG. 3.—Diagrammatic section (condensed) of rocks exposed in the western part of Colob Plateau. (The names are used in a quotational sense, from Huntington and Goldthwait, Bull. Harvard Coll. Mus. Comp. Zool., vol. 42, 1904, pp. 203-204.)

The following is the complete detailed section of the rocks of Colob Plateau, which are also shown diagrammatically in fig. 3.

Section of rocks exposed in Colob Plateau.

(A) AT KANARRAVILLE COAL MINE.

	Feet.
1. Basalt on eroded surface at Kanarraville, but Eocene conglomerate in other places	(?)
2. Limestone, shaly, containing *Ostrea* sp., *Cyrena securis* Meek?, *Corbula nematophora* Meek	50
3. Not exposed	50
4. Sandstone, yellow, friable, containing *Ostrea soleniscus* Meek, *Inoceramus labiatus* Schloth., *Cyrena securus* Meek?, *Modiola* sp	50
5. Sandstone, massive, gray, with layers of sandy limestone containing oysters	175

	Feet.
6. Sandstone and shale, partly covered, containing *Cyrena securis* Meek?, *Corbula nematophora* Meek	115
7. Shale, black, carbonaceous, with thin bands of limestone containing *Avicula gastrodes* Meek, *Cardium pauperculum* Meek, *Glauconia coalvillensis* (Meek)	15
8. *Coal* with bands of earthy limestone containing *Ostrea* sp., *Cyrena* sp., *Corbula nematophora* Meek. (Probably the same as the coal of No. 9, below)	8

(B) IN COAL CREEK CANYON.

9. Shale, black, carbonaceous, with *coal bed* about 4 feet thick (Lunt mine).	55
10. Sandstone, massive, gray, coarse, cross-bedded, conglomeratic in places and containing *Ostrea* sp	30
11. Shale, carbonaceous, with 6-inch *coal bed*	5
12. Sandstone, massive, gray	10
13. Limestone, sandy, containing *Ostrea* sp., *Glauconia coalvillensis* (Meek)	2
14. Sandstone, massive, gray	15
15. Shale, black, carbonaceous, with thin beds of *coal*	10
16. Sandstone, light colored, alternating with layers of shale of various shades of pink, green, blue, etc	500
17. Sandstone, massive, gray, cross-bedded	50
18. Shale, weathering to many shades of red, green, etc	225
19. Conglomerate, consisting of quartzite, limestone, and red-sandstone pebbles	5
Erosional unconformity.	
20. Sandstone, red, friable, and sandy shale	100
21. Gypsum	100+
22. Shale, red	150
23. Limestone, brown, earthy, forming a cliff	250
24. Sandstone, red, shale, and gypsum	40
25. Sandstone, massive, red; makes a conspicuous cliff	1,050
26. Sandstone, red, alternating with layers of shale	175
27. Sandstone, massive, red	475
28. Sandstone, thin bedded, red, purple, and gray, and shale in alternating layers	180
29. Sandstone, massive, cross-bedded, red	250
30. Sandstones and shales, thin bedded, red	520
31. Sandstone, conglomeratic, coarse, gray, with fossil wood at the base. (*Araucarioxylon arizonicum*)	100
32. Sandstones in alternating layers of purple, red, and gray, and shales, with numerous beds of gypsum	2,150
33. Limestone, earthy, containing the same fossils as those of No. 33 below	(?)

(C) 5 MILES SOUTH OF KANARRAVILLE.

34. Limestone, earthy, containing *Composita* sp., *Pugnax* aff. *osagensis*, *Dielasma* (?) sp., *Aviculipecten* aff. *occidentalis*, *Aviculipecten* sp., *Myalina* aff. *permiana*, *Bakewellia* n. sp., *Schizodus* sp	100
35. Shale, red, sandy	400
36. Limestone with small pebbles	50
37. Conglomerate, pebbles of quartzite, limestone, etc., in lime matrix	125
Unconformity.	
38. Limestone, massive, base not exposed	300+

BEAVER CANYON.

No fossils were collected from the lower massive limestone (No. 38) in the Kanarraville region, but a small collection was made in Beaver Canyon, about 50 miles to the north, from a limestone which is apparently the same. The faunas of the overlying red beds were also found much better preserved in Beaver Canyon than farther south. For this reason it is thought desirable to include the Beaver Canyon section in this paper, although it is outside of the area described.

Section of rocks exposed in Beaver Canyon 4 miles east of Minersville.

	Feet.
1. Several hundred feet of basalt.	
2. Many hundred feet of rhyolitic flow, tuff, and breccia.	
3. Several hundred feet of andesitic flow, tuff, and breccia.	
4. Gravel, uncemented, and bowlders of limestone, quartzite, and andesite ..	250
5. Conglomerate, coarse, consolidated, consisting of limestone, quartzite and various crystalline rocks, the bowlders having a maximum diameter of 5 feet	90
Unconformity.	
6. Shale, red	60
7. Limestone, earthy gray	15
8. Shale, red	10
9. Limestone, gray	10
10. Shale, red, and ripple-marked sandstones	40
11. Limestone, blue	10
12. Shale, red, and ripple-marked sandstones	120
13. Limestone containing *Aviculipecten weberensis*, *Aviculipecten* aff. *occidentalis*, *Myalina* aff. *perattenuata*, *Bakewellia* n. sp., *Pleurophorus* sp., *Schizodus* sp	15
14. Shale	40
15. Limestone containing same fossils as No. 13	15
16. Shale, buff, with a small amount of limestone	95
17. Shale and limestone containing *Aviculipecten* n. sp., *Pleurotomaria?* sp., *Bakewellia* n. sp., *Naticopsis* sp., *Xenodiscus?* sp., undetermined ammonoids	100
18. Shale, red	35
19. Shale, yellowish brown, alternating with ripple-marked sandstone	40
20. Conglomerate, quartzitic	10
Unconformity.	
21. Limestone, cherty, containing *Zaphrentis?* sp., *Fistulipora* sp., *Septopora* sp., *Productus* aff. *subhorridus*, *Meekella?* sp., *Spirifer* aff. *cameratus*, *Squamularia* aff. *perplexa*, *Spiriferina* aff. *kentuckyensis*, *Spiriferina* sp., *Composita* aff. *subtilita*, *Hustedia* aff. *meekana*, *Pugnax* aff. *osagensis*	450
22. Quartzite, yellowish	200
23. Limestone, cherty, containing *Squamularia*? sp. and *Hustedia* aff. *meekana*	500
Base not exposed.	
	2,105

CORRELATIONS.

AUBREY LIMESTONE (CARBONIFEROUS).

The limestone (No. 38) at the base of the Colob Plateau section is referred with some doubt to the Aubrey formation of the Carboniferous. It is apparently the same as the limestone forming the base of

the exposed section in Le Verkin Canyon, southeast of Kanarraville, referred to the Aubrey by Huntington and Goldthwait,[a] who traced the formations from the Grand Canyon in northern Arizona northward along the Hurricane fault to Kanarraville. The fauna yielded by the massive limestone beneath the red beds of the Beaver Canyon section, which from stratigraphic evidence is supposed to be the same as the limestone at the base of Colob Plateau, is stated by G. H. Girty,[b] who identified the fossils, to be probably Aubrey, although it does not contain the most characteristic Aubrey forms.

RED ROCKS.

Resting unconformably upon the basal limestone of the section is an extensive group of red sediments. Fossiliferous limestone was found at a few horizons near the base of this group in the Beaver Canyon section, and on the basis of the fossil evidence Doctor Girty correlates the beds with Walcott's Permian of the Grand Canyon section[c] and with the "Permo-Carboniferous" of the Wasatch Mountain section.

The only other stratum found to be fossiliferous within the red beds is the conglomeratic sandstone (No. 31), which contains petrified tree trunks. Thin sections of the wood have been examined by David White and F. H. Knowlton, of the United States National Museum. Doctor Knowlton recognizes the form as *Araucarioxylon arizonicum*, described by him from the Shinarump conglomerate of Arizona. This determination strengthens the stratigraphic evidence that the conglomeratic sandstone of this section is to be correlated with the Shinarump of Arizona, which Ward[d] refers to the Triassic. It is noteworthy that although Ward describes the lower or conglomeratic part of the Shinarump of Arizona as 800 feet thick, the formation here reaches only 100 feet. It is possible, however, that some of the overlying red strata may belong in the Shinarump instead of in the Painted Desert formation.

The lower part of the section given by Huntington and Goldthwait in the paper just referred to is very similar to the section in Colob Plateau, and the names there given may be employed so far as the formations can be recognized. The Moencopie (Permian ?) probably includes all the red sediments between the Aubrey limestone (No. 38) and the Shinarump conglomerate (No. 31), a thickness of about 2,800 feet. There is apparently a time break at the base of

[a] Huntington, Ellsworth, and Goldthwait, J. W., The Hurricane fault in the Toquerville district, Utah: Bull. Mus. Comp. Zool., Harvard Coll., vol. 42 (Geol. Ser., vol. 6), 1904, pp. 199-259.

[b] Personal communication.

[c] Walcott, C. D., The Permian and other Paleozoic groups of the Kanab Valley, Arizona: Am. Jour. Sci., 3d ser., vol. 20, 1880, pp. 221-225.

[d] Ward, S. F., Geology of the Little Colorado Valley, Arizona: Am. Jour. Sci., 4th ser., vol. 12, 1901, p. 405.

this conglomerate which may represent the interval between the Permian (?) and that part of the Triassic represented by the conglomerate. The abrupt change from the red gypsiferous shale and sandstone of the Moencopie to the gray conglomeratic sandstone of the Shinarump and the presence within the conglomerate of pebbles of quartzite and argillite suggest that the Shinarump is a basal formation deposited upon a surface of erosion.

No data were obtained regarding the age of the red sediments overlying the Shinarump conglomerate. The shales and sandstones of No. 30 may be the Leroux or may be the Painted Desert formation of Huntington and Goldthwait. The Kanab sandstone (Nos. 25 to 29, inclusive), has here a thickness of about 2,800 feet, the upper half consisting of massive red sandstone that forms conspicuous cliffs.

The Colob formation of Huntington and Goldthwait was not recognized. The Kanab sandstone is overlain in the Coal Creek canyon by gypsum, earthy limestone, and red sandstone and shale, separated into two nearly equal subdivisions by a conglomerate resting apparently upon an eroded surface. This was observed in only one place, and its significance was not determined. No evidence of the geologic age of the two divisions was found further than the fact that they are younger than the Kanab sandstone and older than the Benton.

BENTON.

The upper part of the section, or coal-bearing members (Nos. 1 to 19), is shown by paleontologic evidence to belong to the Benton subdivision of the Cretaceous. Dutton [a] stated that coal or carbonaceous shale is found at many horizons from the base to the summit of the Cretaceous rocks through a thickness of 3,500 to 8,000 feet. Later, Stanton [b] described briefly the coal-bearing formation of Colob Plateau and showed that it contained plant remains and fresh-water shells in some places and marine shells in others.

The fossils collected by the writer, most of which have been named in the foregoing section, were determined by T. W. Stanton, who states [c] that the formation may be correlated with the coal-bearing rocks of Coalville, Utah, and with a part of the Frontier formation

[a] Dutton, C. E., Report on the geology of the high plateaus of Utah, U. S. Geog. and Geol. Survey Rocky Mts., 1880, xxxii+307 pp.; Tertiary history of the Grand Canyon district: Mon. U. S. Geol. Survey, vol. 2, 1882.

[b] Stanton, T. W., The Colorado formation and its invertebrate fauna: Bull. U. S. Geol. Survey No. 106, 1893, p. 36.

[c] Personal communication.

in western Wyoming. A few of the fossils were collected from localities not represented in the section. The following is a complete list:

Ostrea soleniscus.
Ostrea sp.
Anomia sp.
Avicula gastrodes Meek.
Barbatia micronema (Meek).
Trigonarca obliqua Meek.
Cyrena securis Meek?
Cyrene sp.
Corbula nematopora Meek.
Cardium pauperculum Meek.
Eulemella (?) funicula Meek.
Admetopsis subfusiformis Meek.
Glauconia coalvillensis (Meek).
Chemnitzia? sp.
Inoceramus labiatus Schlotheim?
Modiola sp.
Physa.
Planorbis.

STRUCTURE.

The cliffs forming the western face of Colob Plateau constitute the northward extension of the Hurricane Cliffs, the great difference in elevation—a maximum of about 4,000 feet—between the plateau and the basin to the west being due to displacements along the line of the Hurricane fault. As already stated, Huntington and Goldthwait traced this fault from the Grand Canyon northward to Kanarraville, and showed that at the latter place, as elsewhere, there is an old and a new Hurricane fault. The sequence of events worked out by these authors is (1) a period of flexing of the strata followed by a period of erosion; (2) the formation of the old Hurricane fault, followed by a long period of erosion, during which a considerable area was reduced to a peneplain; (3) the formation of the younger Hurricane fault and the uplift of the plateau.

During his brief stay in the region directly north of the area described by Huntington and Goldthwait, the writer saw little evidence of the existence of a fold, but was impressed with the profound faults and tilted blocks plainly to be seen near the edge of the plateau. From Beaver River southward to New Harmony, wherever the sedimentary formations were observed west of the plateau, they dip eastward toward the cliffs. In several places in the plateau also, near its margin, large blocks of eastward-dipping sedimentary rocks were observed. A conspicuous example occurs between Kanarraville and Shirtz Canyon, where the strata are tilted 30° to 45°. In other places, as, for example, along the road leading from Kanarraville to the Kanarraville coal mine, the strata are vertical or overturned, forming, according to Huntington and Goldthwait, the eastern limb of an overturned fold, which later was eroded and faulted as illustrated in fig. 8 of their paper on the Hurricane fault.

In the vicinity of Cedar City faults are not confined to the margin of the plateau. In the canyon of Coal Creek several faulted blocks were observed, some of them let down nearly 3,000 feet with the strata remaining essentially horizontal. The structure is complicated, and careful examination is necessary before the region can be described in detail.

CHARACTER OF COAL-BEARING ROCKS.

The various coal openings on the plateau are at essentially the same stratigraphic horizon and are probably all on the same coal bed. It is significant in this connection that a thin limestone containing *Admetopsis subfusiformis* Meek and *Eulimella funicula* Meek (locally known as screw shells) lies about 100 feet above the coal and is used by prospectors as a guide stratum in locating the coal bed. Several prospects have been successfully located in this way where the coal was covered with slide rock.

Coal occurs at other horizons in Colob Plateau, although not in workable thicknesses so far as known. Thin coal beds occur 60 feet below the main bed, which is worked in the vicinity of Cedar City and Kanarraville (No. 8 of the accompanying section), and carbonaceous shale containing coal was also noted 1,000 feet above the main bed at Wood & Taylor's mine in the Coal Creek canyon. These observations tend to confirm Dutton's statement that coal occurs at several horizons and render it possible that the New Harmony coal beds, which seem to differ so markedly from those best known in Colob Plateau, as here described, may belong to some horizon not yet known in the plateau region.

The coal beds occur in a formation which is essentially marine, as shown by the fossils. In places, however, it contains plant remains and fresh-water mollusks, according to Stanton,[a] and in others such brackish-water genera as *Ostrea*, *Cyrena*, and *Corbula*. The coal itself contains thin seams and lenticular masses of earthy limestone that carry in some places marine fossils, in others brackish-water fossils, and in still others such fresh-water genera as *Physa* and *Planorbis*. It is evident that the coal accumulated at the shore of the Cretaceous sea under alternating marine and fresh-water conditions.

DESCRIPTIVE DETAILS OF COAL.

Although the coal of southwestern Utah has been utilized since 1854, few mines have been opened and the coal has been used only in the small towns located near the coal outcrops. For this reason, and probably also because the coal is exposed at the surface at many points along the outcrop, little prospecting has been done. The few mines that have been worked are described in the following paragraphs, the numbers corresponding with the location numbers on Pl. XXI (p. 360).

1. JONES & BULLOCK MINE.

The Jones & Bullock mine is located in the SE. ¼ sec. 36, T. 36 S., R. 10 W., in the Coal Creek canyon, about 8 miles southeast of Cedar City. The coal bed lies nearly horizontal at an altitude of about

[a] Stanton, T. W., The Colorado formation and its invertebrate fauna: Bull. U. S. Geol. Survey No. 106, 1893, p. 36.

7,200 feet, the coal-bearing formation, which farther south caps the plateau at an altitude of nearly 10,000 feet, having been faulted down so that the coal is brought within 50 feet of the bottom of the canyon. The mine is located near the wagon road between Cedar City and Panguitch and is more easily accessible than any other workings visited in southwestern Utah. It has been operated more or less continuously since 1890, with a maximum output of about 300 tons a year. An entry has been run in on the coal bed for 250 feet. Little care has been exercised in working the mine and the entry has been broadened by the removal of the coal, the waste piled in the vacated space being in places the only support for the roof. The section exposed in the mine is as follows:

Section of coal bed in Jones & Bullock mine.

	Ft.	in.
Coal, impure, discarded in mining	1	
Clay		8½
Coal	3	10½
	5	7

The surface is covered with slide rock at this place and no indication was observed of coal at other horizons.

2. CLUFF (JENSEN) MINE.

The Cluff or Jensen mine, now owned by Peter Feiff, is located in sec. 35, T. 36 S., R. 10 W., in the Coal Creek canyon, 7 miles east of Cedar City. The coal-bearing formation is here faulted down, as already described, bringing the coal bed to the bottom of the canyon. The mine was opened in 1885. The entry, which is driven in on the coal bed, is said to be 600 feet long and the coal 5½ to 6 feet thick. The mine was inaccessible at the time of the writer's visit, and apparently had not been worked for several years.

3. WOOD & TAYLOR MINE.

The Wood & Taylor mine is located in the NW. ¼ sec. 4, T. 37 S., R. 10 W., in the canyon of the south fork of Coal Creek, about 7 miles southeast of Cedar City and near the top of the plateau, at an altitude of about 8,900 feet. In order to reach it an ascent of 2,000 feet or more must be made up the precipitous side of the canyon. The difficulty of hauling coal from such a place materially lessens the value of the mine.

The mine was opened in 1881 and has been worked more or less continuously since that time. The market is local and very small, little of the coal being used outside of Cedar City. The average output is reported to be about 50 tons a year, with a maximum of 250 tons. The coal bed is nearly horizontal and is overlain by about

1,000 feet of rock. An entry has been run in on the coal bed for 390 feet from the face of the cliff. At the end of the entry the following section was measured:

Section of coal bed in Wood & Taylor mine.

	Ft.	in.
Limestone containing *Cyrena securis* Meek?		
Coal, bony—discarded in mining	2	
Clay		5
Coal		10½
Shale, carbonaceous, containing numerous specimens of *Physa*, *Planorbis*, and perhaps other fresh-water shells		1
Coal		6
Clay		3½
Coal	2	1
Clay		1
Coal	2	1
Limestone.		
	8	5

Coke is said to have been made from this coal many years ago and used locally for the extraction of iron from the ores that occur in great abundance in the Iron Mountains. The coke is said to have been satisfactory for smelting purposes. For some time iron was produced at the rate of 3 or 4 tons a day, but its quality was poor, and smelting was discontinued when the advent of railroads made possible the importation of better iron from the East. Coke made from the Wood & Taylor coal is said to have been used successfully also in the Horn Silver smelter, but for some reason coking has not been continued.

A quarter of a mile north of the old Wood & Taylor mine a new one, No. 4 of the map, has been opened on the same coal bed, but no coal has yet been shipped.

5. LEYSON MINE.

The Leyson mine is located in the SE. ¼ sec. 33, T. 36 S., R. 10 W., about a mile north of the Wood & Taylor mine, but is not now in operation. It is said to have been the first mine opened in Utah, and was operated from 1854 until 1890. The first coke ovens in southwestern Utah were built near this mine and the early settlers used the coke for smelting iron. Later 200 to 300 tons of it were hauled to Frisco for smelting purposes.

OTHER OPENINGS IN COAL CREEK CANYON.

Several openings have been made in the canyon of Coal Creek and abandoned for various reasons. Some of these openings are indicated on the map without location number, but the location of the Lunt mine (No. 6), so called, although it was little more than a prospect, is shown for the purpose of marking that part of the accompanying

section (Nos. 9–22) which was measured there. The prospects north of Coal Creek have failed principally because of the faulted and contorted condition of the rocks and the consequent crushing of the coal beds.

7. CORRY MINE.

Andrew Corry's mine is located in sec. 25(?), T. 36 S., R. 11 W., at the western edge of Colob Plateau, about 4 miles southeast of Cedar City, at an altitude of about 9,000 feet. The opening is in the face of the precipitous escarpment, 3,000 feet above Cedar City and 500 feet below the top of the plateau. The plateau is here covered with basalt, and the sediments are cut by large dikes, but no evidence of extensive metamorphism was found. The road from the town to the plateau passes the mine, but it is very steep, and hauling coal from the mine is difficult and expensive.

The mine was opened in 1885 and has been worked occasionally since that time, the coal being used almost entirely in Cedar City. The entry runs in on the coal bed for about 50 feet and then turns parallel to the face of the cliff. Little care has been exercised in mining and the roof has fallen in several places, rendering access to the mine difficult. The end of the entry, however, was found in good condition, and there the following section was measured:

Section of coal bed in Corry mine.

	Ft.	In.
Shale, carbonaceous and calcareous.		
Coal, containing a quarter-inch streak of clay	1	
Clay		1
Coal		5
Clay		1
Coal	2	
Clay.		
	3	7

The impurities in the coal vary greatly in quantity and character from place to place.

Here, as elsewhere in southwestern Utah, marine shells occur in lenses and seams of limestone within the coal. *Corbula nematophora* Meek and *Glauconia coalvillensis* Meek were obtained in the Corry mine in blocks of rock which apparently had fallen from the roof.

8. CULVER MINE.

F. L. Culver's mine is located in sec. 24, T. 37 S., R. 11 W., at the western margin of Colob Plateau, in Shirts Canyon, at an elevation of 8,900 feet, or about 3,000 feet above the base of the plateau. The coal bed is near the base of the Benton (Cretaceous) formation and at this point strikes N. 10° E., dips 8° SE., and is overlain by 900 feet of rock. This thickness increases eastward or down the dip, the surface of the plateau being essentially level. The face of the cliff is

covered with talus, and the distance of the coal bed above the base of the Benton formation was not determined, nor is it known that this is the only coal bed of workable thickness.

The mine is most conveniently reached from Cedar City by a wagon road that has recently been built up Shirts Canyon. The coal was first opened in 1903, when an entry was run in on the bed for 175 feet. Nothing more was done until the summer of 1906, when the property was acquired by Mr. Culver and work was begun with the intention of active operation, although no coal had been shipped at the time the mine was visited. The section exposed within the mine is as follows:

Section of coal bed in Culver mine.

	Ft.	in.
Shale, carbonaceous.		
Coal	6	11
Limestone, earthy, containing *Cyrena* sp. and *Corbula nematophora* Meek	2	
Coal	2	
Limestone.		
	10	11

9. KANARRAVILLE MINE.

Only one mine is now in operation near Kanarraville. This is located in sec. 29, T. 37 S., R. 11 W., at the western margin of Colob Plateau, 4 miles northeast of the town, at an altitude of about 8,500 feet, or 3,000 feet above the base of the plateau. It is reached from Kanarraville by a public road leading to the plateau. The mine, first opened in 1886, is now owned by the Southwestern Coal and Iron Company, of Salt Lake City. Little coal is mined, probably because of the difficulties of cartage. About 80 tons is said to be the average yearly output. The coal dips 5° E., or toward the plateau, and the entry has been run in on the coal for 270 feet.

Section of coal bed in Kanarraville mine.

	Ft.	in.
Clay and earthy limestone containing *Avicula gastrodes* Meek, *Cardium pauperculum* Meek, *Glauconia coalvillensis* (Meek).		
Coal	1	9
Clay		4
Coal		2
Clay		2
Coal	3	6
Clay		1
Coal	1	11
Limestone, earthy, containing *Ostrea* sp., *Cyrena* sp., *Corbula nematophora* Meek		5
Coal.		
	8	4

The lowest bench of coal was not exposed and nothing was learned of it further than the fact that it forms the floor of the mine.

About half a mile north of the Kanarraville mine is an old opening, coal from which is said to have been coked years ago. The ruins of the old ovens are still there, but nothing further was learned in regard to it.

10. NEW HARMONY MINES.

Several mines are located in sec. 32, T. 27 S., R. 13 W., about 4 miles north of New Harmony, on the east flank of one of the spurs of Pine Valley Mountain, at an altitude of about 6,000 feet. Preliminary surveys show that a branch might easily be constructed connecting the mines with the San Pedro, Los Angeles and Salt Lake Railroad, about 40 miles to the west.

The coal-bearing sediments consist of dark-colored shale, sandstone, and earthy limestone. The base of the formation was not seen and the upper 600 feet are poorly exposed. The rocks are faulted and the sequence of the beds can not be determined without much detailed work. A section, however, has been measured across a part of the coal-bearing strata by Robert A. Kirker, who has kindly permitted its use in this report. The measurements were made in shafts and prospect entries and are thought to be exact. Mr. Kirker states that a coal bed 9 feet 4 inches thick occurs below the base of the section and two beds 4 feet 10 inches thick and 5 feet 2 inches thick above the top, but they are imperfectly known, being exposed only in open cuts, and their position in the column has not been determined.

Section of a part of the coal-bearing beds near New Harmony, Utah.

[By Robert A. Kirker.]

	Ft.	In.
Igneous intrusive	10	4
Shale, calcareous	10	4
Sandstone	9	5
Coal, bony	4	8
Clay	2	10
Coal, bony	9	5
Sandstone	17	10
Coal No. 3 (sample for analysis No. 6)	4	5
Shale		3
Limestone, fossiliferous	15	
Sandstone	9	5
Clay	2	10
Shale		3
Coal No. 4 (sample for analysis No. 7)	4	8
Clay shale	2	10
Coal, bony	1	11
Fire clay	5	2
Shale, dark	4	8
Shale	2	10
Sandstone	11	3
Coal		3
Limestone, earthy	4	8

	Ft.	In.
Shale, calcareous	2	10
Coal, bony	5	8
Clay shale	2	10
Coal, bony	1	5
Shale, dark	1	5
Clay	1	11
Limestone, gray, shaly	9	5
Coal, bony	1	11
Shale, calcareous	2	10
Shale, green	4	1
Coal, bony	5	4
Shale, black	5	
Igneous intrusive.		
	179	11

The coal-bearing rocks belong to the Benton (Cretaceous) formation, as shown by the following fossils found at this locality:

Ostrea sp.
Cyrena securis Meek?
Corbula nematophora Meek.
Glauconia coalvillensis (Meek).
Chemnitzia? sp.
Planorbis.

The fauna is the same as that of the coal-bearing rocks of Colob Plateau, but does not prove that the New Harmony coal occurs at the same horizon as that of the plateau, inasmuch as these fossils occur through the entire thickness of the formation. The coal at Kanarraville and Cedar City is near the base of the Benton, while that at New Harmony is near the top of whatever Benton is there present. The overlying rocks were removed by erosion previous to the deposition of the Eocene, which here rests upon the Benton, and consequently it was impossible to determine whether the New Harmony coal occurs at the same horizon as that of the plateau, or whether it occurs at some higher horizon of which little is yet known. The New Harmony mines are only 12 miles in a straight line from the nearest outcrop of coal in the plateau, a distance apparently too small to account for the great difference in the character of the formation and the number of coal beds on the assumption that the coals of both localities belong to the same horizon.

Owing to the crushed and contorted condition of the strata near New Harmony, there is a possibility that the several coal beds reported by Mr. Kirker may be to some extent due to duplication by faulting, the difference in thickness and character of the coal being caused by crushing. This possibility was carefully considered by Mr. Kirker in making his section, and the writer found no evidence that his conclusion in reference to the number of coal beds is not correct.

Resting unconformably upon the coal-bearing rocks is a formation consisting of conglomerate at the base, overlain by pink shale and

coarse, friable sandstone, with deep-red or vermilion sandstone, shale, and pink cherty limestone near the top. This formation is identical in physical character with the Eocene sediments of the plateau to the east, and although no fossils were obtained to confirm the correlation, it is unquestionably of Eocene age. This formation, together with the underlying coal measures, is faulted and intersected by dikes of andesite and rhyolite; it is also overlain by masses of the same rocks.

QUALITY OF COAL.

Seven samples of coal were collected from the Iron County mines. The samples were taken across the beds, quartered and pulverized in the mines, and sent in sealed cans to the chemical laboratory of the United States Geological Survey fuel-testing plant at St. Louis, Mo. The results are as follows:

Proximate analyses of coals from Iron County, Utah.

[F. M. Stanton, analyst.]

	I.	II.	III.	IV.	V.	VI.	VII.
Laboratory No.	3687	3760	3761	3762	3830	3793	3794
Analysis of sample as received:							
Moisture	13.20	4.92	5.24	8.54	13.35	11.01	4.61
Volatile matter	35.58	37.96	39.82	36.45	38.34	10.39	5.11
Fixed carbon	41.75	43.18	43.44	46.22	42.95	36.09	47.31
Ash	9.47	13.94	11.50	8.79	5.36	42.51	42.97
Sulphur	4.42	6.56	6.81	5.85	5.74	3.27	4.44
Loss of moisture on air drying	5.40	2.10	1.70	2.30	5.00	7.90	2.40
Analysis of air-dried sample:							
Moisture	8.24	2.88	3.60	6.38	8.80	3.38	2.26
Volatile matter	37.62	38.77	40.51	37.31	40.35	11.28	5.24
Fixed carbon	44.13	44.11	44.19	47.31	45.21	39.18	48.47
Ash	10.01	14.24	11.70	9.00	5.64	46.16	44.03
Sulphur	4.67	6.70	6.93	5.99	6.04	3.55	4.55

I. Sec. 24, T. 37 S., R. 11 W.; near top of plateau, altitude 8,900 feet.
II. SE. ¼ sec. 4, T. 37 S., R. 10 W.; Coal Creek canyon, altitude 7,900 feet.
III. Sec. 25 (?), T. 36 S., R. 10 W.; near top of plateau, altitude about 8,700 feet.
IV. SE. ¼ sec. 36, T. 36 S., R. 10 W.; Coal Creek canyon, altitude 7,200 feet.
V. Sec. 28, T. 37 S., R. 11 W.; near top of plateau, altitude 8,500 feet.
VI. Four miles north of New Harmony; altitude 6,200 feet.
VII. Do.

The coal of the plateau, so far as examined, has not been notably affected by local metamorphism. It is uniform in character, and black and glistening in appearance when first taken from the mine, although it soon slacks when exposed to the air. It is locally called black lignite, but in the absence of ultimate chemical analyses no attempt is here made to classify it.

More is to be said, however, of the New Harmony coal, which has been greatly disturbed by faulting, crushing, and intrusions of igneous rock and metamorphosed to a semianthracite. The development of the coal prospects is yet at an experimental stage, and in few places was clean, uncrushed coal to be found. The samples taken in the usual way across the beds include much foreign matter from

the crushed portions, causing the high percentage of ash shown in the analyses. The uncrushed parts show bright, glistening cleavage faces and contain much smaller percentages of ash than those shown in analyses 6 and 7 of the foregoing table.

Three selected samples of this coal have been analyzed by Herman Harms, State chemist of Utah, with results as given below. The information was kindly furnished by Robert A. Kirker, manager of the Harmony Coal Company's mines.

Analyses of selected samples of coal from the New Harmony mines.

[Herman Harms, analyst.]

	1.	2.	3.
Weight of sample.....ounces..	10.5	9.5	3.00
Moisture at 115° C.....per cent..	1.28	.81	.74
Combined volatile matter.....do....	12.58	10.25	12.93
Fixed carbon.....do....	70.11	75.11	73.72
Sulphur.....do....	4.38	1.97	2.64
Ash.....do....	11.65	13.83	12.61

Probably the most important consideration in regard to the coal of Iron County is its proximity to the deposits of iron ore in the Iron Mountains. The ore is too remote from the existing smelters to be profitably utilized at the present time. The iron properties, however, are being rapidly acquired by large operators and will eventually be productive. It is possible that the coal might be used for smelting the ore near the mines. The New Harmony semianthracite may, perhaps, prove satisfactory for this purpose if it can be obtained sufficiently free from impurities, but the coal of the plateau would require coking.

Reports differ regarding the coking qualities of the coal. To judge from local accounts it produces a coke of inferior quality. A satisfactory coke is said to have been made from it recently by some secret process, but the writer was not able to learn where or by whom this was done.

A RECONNAISSANCE SURVEY OF THE WESTERN PART OF THE DURANGO-GALLUP COAL FIELD OF COLORADO AND NEW MEXICO.[a]

By MILLARD K. SHALER.

INTRODUCTION.

The area of the Durango-Gallup coal field includes 13,500 square miles, of which 1,900 lie in Colorado and the remainder in New Mexico. The total production of coal in this field in 1905[b] was about 660,600 short tons, valued at nearly $1,000,000, exclusive of coke, of which about 12,000 short tons were produced. The entire tonnage of the field is estimated at 80,000,000,000 short tons, by figuring conservatively on a total workable thickness of 6 feet underlying the area, although 10 feet is probably a closer approximation of the average.

The Durango-Gallup coal field extends from the latitude of Durango, Colo., on the north to the latitude of Salt Lake, 70 miles south of Gallup, N. Mex., on the south, a distance of about 200 miles. Chama, Elvado, and the Sierra Nacimiento, in longitude 106° 45′, are situated near the eastern boundary of the field, and its western limit is the New Mexico-Arizona boundary line. The width of the field is about 150 miles. (See Pl. XXII.)

In altitude the surface ranges from 5,000 to 9,000 feet, with an average of about 6,500 feet. The topography is varied, but on the whole the country is an open plateau in which the streams have cut valleys nearly 1,000 feet in depth.

This paper, as may be seen by reference to the map, treats only of that part of the Durango-Gallup field lying west of longitude 107° 30′; hence the remainder of the area will be given no further consideration.[c] The principal towns in Colorado within the region here considered are Durango and Mancos, located on the Denver and Rio

[a] This preliminary report will be followed by a fuller description of the entire field, now in preparation, which will appear at an early date as a publication of the Survey.

[b] Mineral Resources U. S. Figures for 1906 are not yet available.

[c] For a preliminary report on the entire field, but more particularly on the eastern part of it, see Schrader, F. C., The Durango-Gallup coal field: Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258.

Ft. Defiance
Bonito Cree
NAVAJO IND. RES. LINE
Dalton's Store
Little Togay Spr.
Mariano Lake
HOSTA BUTTE
Weidemeyer Store
Gibson
Clarkville
CONTINENTAL DIVID

UNIVERSITY

Grande Railroad. In New Mexico Gallup, McKinley County, situated on the Atchison, Topeka and Santa Fe Railway, is the only important town in the area.

The coal beds occur in the Upper Cretaceous, and have a maximum thickness of nearly 80 feet, with an average for the workable beds of about 10 feet. The better coals occur in the northern part of the area in the Mesaverde formation.[a] The thicker coal beds occur in the Laramie formation, but they are of poorer quality than those of the Mesaverde. Coal beds also occur in the Mancos and Dakota formations. The character of the coals varies from subbituminous[b] to a good grade of bituminous.

The field work on which this report is based was of a rapid reconnaissance nature throughout and was done mainly during the autumn of 1906. For assistance in the preparation of the report, the writer wishes to acknowledge his indebtedness to Mr. James H. Gardner, who rendered valuable services in both field and office.

GENERAL GEOLOGY.

STRATIGRAPHY.

Fossils collected by this party in 1906 and by Schrader's party during the previous year, which were studied by Stanton and Knowlton, indicate that the several formations observed and mapped in the field have the time values shown in the accompanying table. In classifying the Cretaceous sediments the formation names of Cross[c] are followed as nearly as their limits could be interpreted.

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[a] Cross, Whitman, Geologic Atlas U. S., La Plata folio (No. 60), U. S. Geol. Survey, 1899.

[b] The term subbituminous has been adopted by the Geological Survey for that class of coal commonly known as "black lignite."

[c] Op. cit.

Stratigraphic succession, age of beds, and tentative correlations in Durango-Gallup coal field, Colorado-New Mexico.

System.	Series.	Formation or group.[a]	Character of strata.			Where exposed.			Thickness.			Economic value.
			North area.	Central area.	South area.	North area.	Central area.	South area.	North area.	Central area.	South area.	
Quaternary.	Recent.		Terrace gravel, alluvial wash, and flood-plain deposits, with chert fragments in central area and hot-spring deposits in south area.			Variably throughout field.			*Feet.* 0-200	*Feet.* (?)	*Feet.* (?)	Residual clays used for brickmaking.
			Unconformity.									
	Pleistocene (?).		Conglomerate; sandy matrix, angular, fine gravels of red quartzite.			Well developed along La Plata River between Laplata and Fruitland, N. Mex.			4-40			
			Unconformity.									
(?)	Eocene or post-Eocene.		Rhyolite, rhyolitic tuff, and dikes of biotite monchiquite.		Basic lavas locally amygdaloidal; amygdules filled with secondary calcite.	Dikes, flows, and isolated necks as in Ship Rock.		Occupies large areas between Zuni and Inscription Rock and farther south.	(b)	200+	0-100+	
			Unconformity.									
Tertiary.	Eocene.	Wasatch (?).	Sandstones, conglomerates, and clay shales.		Unconsolidated pinkish sand, drabmud shale, and conglomerate with pink sandy matrix.	East of Animas River and in Canyon Largo.		Locally present south of Gallup, occupying top of mesa north of Salt Lake.	1,200+		0-500	Shales might be used for brickmaking.
			Unconformity (?).									
		Puerco marl.	Dark-colored marl, unconsolidated sand, thin sandstone and conglomerate beds (fossil mammals and silicified wood).			Along Animas River below Carbon Junction and east and north of Rio Chaco.	East and north of Rio Chaco and capping Choiskai Mountains (may be Wasatch).		900	1,000+		Marl might be used, in part, for brickmaking.
			Unconformity.									
(?)	Post-Laramie.	Animas formation.	Coarse conglomerate, pink sandy matrix, pebbles and bowlders of quartzite and volcanic rock.			From Carbon Junction east and west, and east of McDermott Arroyo.			0-300			

Unconformity.

Cretaceous.	Upper Cretaceous.	Laramie formation.	Massive gray sandstone at base, above which are coal beds and alternating sandstone and shale beds.		Basin Mountains; east of McDermott Arroyo in Colorado; east of The Meadows in New Mexico.	East and north of Rio Chaco.		500–1,000	200–800		Contains workable coal beds, above basal massive sandstone. Sandstone excellent for building and some of shale beds might be utilized in brick-making.
		Lewis shale.	Dark-drab clay shale containing limy concretions and thin lenses of limestone.		Forms base of Basin Mountains, covers Fort Lewis Mesa and The Meadows, and crosses San Juan River below Fruitland; outcrops in narrow band east and north of Rio Chaco.			1,600	250–2,000		Could be used, in part, for manufacture of clay products.
		Mesaverde formation.	Consists of two massive sandstones between which occur thin sandstone and shale beds, interstratified and including workable coal beds.	Massive sandstones and interbedded drab shales and coal beds.	Caps Mesa Verde and prominent highlands east, west, and south of Durango; is a prominent escarpment maker.	Occurs in Great Hogback; covered by Tertiary in Choiskai Mountains; surface rock in Gallup Basin, in Nutria monocline and eastward.	In Zuni Basin north of latitude of Nutria.	[c] 750–[d] 1,450	1,500+	1,000+	Contains valuable coal beds, especially in upper and lower parts of formation. Commercially valuable beds of fire clay are mined from formation near Gallup. Sandstone excellent for building purposes.
		Mancos shale.	Dark-drab clay shale, slightly arenaceous; contains limy concretions and lenses irregularly.	Dark-drab clay shale, slightly arenaceous; contains limy concretions and lenses irregularly. Transitional sandstone and shale beds interstratified at top, containing a few coal beds.	East and west of Durango; occupies base of escarpments and valleys; forms base of Mesa Verde.	Underlies hogback and borders field throughout area.	Encircles Zuni Basin on east, south, and west sides.	1,000–1,400	750–1,000	750+	Parts used for brick-making at Durango. Is apparently adapted to manufacture of Portland cement. Contains valuable coal beds in southern part of area.
		Dakota sandstone.	Massive hard quartzose sandstone at top; same at base, locally conglomeratic; dark bituminous shale, containing coal bed, locally workable, between sandstones.		Caps Animas City Mountain; outcrops east and west from Durango; occurs at mouth of Mancos River; underlies Great Hogback, or is contained in it.		Borders Zuni Basin; outcrops north of Santa Fe Railway east of Gallup.	100–300	150–300	150–300	Sandstones are good building stones; coal beds locally mined, but generally dirty.

[a] Formation names follow Cross, W., Geologic Atlas U. S., La Plata folio (No. 60), as nearly as possible.
[b] Surface flows up to 200 feet.
[c] Vicinity of Porter, Colo.
[d] San Juan River.

The Dakota is the basal formation of the Cretaceous in this region. Below it occur the Jurassic-Triassic rocks, whose upper beds range in character from the typical "variegated marl series" of Newberry to massive vermilion or white saccharoidal sandstone. An abrupt change from the prevailing drab and tan colors of the Cretaceous rocks to the red, purple, and white of the underlying Mesozoic marks distinctly the lower limit of the coal-bearing formations of the field.

The Mancos shale, which conformably overlies the Dakota, shows a considerable thinning toward the south. The basal two-thirds of the formation maintains to a remarkable extent the same characteristics that mark the whole formation in the vicinity of Mancos, its type locality, but a pronounced though gradual change occurs in its upper portion. Thin sandstone and coal beds of the upper part of the Mancos, their total thickness comprising 150± feet north of Salt Lake, outcrop over a wide area in the Zuni Basin and gradually grade upward into the Mesaverde. Fossils collected from a sandstone member 20 feet below the lowest coal bed mined between Blackrock and Ramah are beyond doubt of Colorado age. No fossils were found, however, in any bed closely overlying this coal; hence there seem to be possible grounds for believing that it lies within the Mesaverde formation.

Throughout its outcrop the Mesaverde maintains in greater part the same lithologic character as in the vicinity of Durango. As will be seen by a reference to the table, it becomes somewhat thicker to the south and contains a greater number of coal beds. In the part of the field near Durango the coal beds occur near the basal sandstone of the formation; in Mesa Verde and the southern part of the field coal is present near both its upper and lower limits.

The Lewis shale, like the Mancos, though in a greater degree, was observed to thin toward the south from 1,600 feet on San Juan River to 250 feet at the mouth of Coal Creek on Rio Chaco. In the north wall of Chaco Canyon, near the mouth of Coal Creek, fossils were collected near the top of the Mesaverde from a limy sandstone immediately overlying a coal bed. A short distance stratigraphically above this sandstone occurs a shale bed 250 feet thick, having the lithologic characteristics of the Lewis. This shale is succeeded by the massive basal sandstone bed of the Laramie, which is overlain by coal. The same thickness of Lewis shale was noted at several points farther east, up the Chaco, establishing beyond question the notable thinning of this formation from its outcrop along the north side of the field.

The Animas beds outcrop only in a narrow belt along the north border of the field, thinning rapidly both east and west from Animas River. If present at all in the central part of the area, they are hidden by the Puerco marl, which north of Pueblo Alto appar-

ently overlaps the Cretaceous rocks. Unconsolidated white sand, unquestionably of Puerco age, here lies in contact with an irregular surface of Laramie coal immediately overlying the basal sandstone member of that formation. At this place the outcropping Laramie is only about 200 feet thick.

The upper and lower limits of the Puerco marl are difficult to determine in the area of flat-lying beds near Rio Chaco. There is nearly everywhere a marked gradation between these rocks and the Laramie, although the main body of the Puerco is easily distinguished by the presence in it of fossil mammal remains and silicified wood.

STRUCTURE.

The structure of the Durango-Gallup field is comparatively simple. The field consists in a general way of a huge basin, complicated in its southwestern portion (Zuni Basin) by what might be termed a crumpling of its upturned edge. This crumpling produced a syncline with north-south axis, parallel to which minor flexures occur near Gallup, in the middle of the basin thus formed. The structure sections on Pl. XXIII depict in a general way these relations. On account of the intimate association of structure and topographic features, however, it seems well to discuss here the main disturbances of the strata.

The disturbances in the northern part of the area are distinctly traceable to two periods—the close of the Cretaceous and the early Tertiary. The main folding in this part of the area occurred after the close of the Cretaceous period. It was the result of an uplift in the San Juan Mountain region, lying to the north, and was later than the deposition of the Animas beds. This disturbance resulted in two folds of the monoclinal type, trending in general southwestward. These folds are, at the longitude of La Plata River, 20 miles apart; but at Animas River and farther east they coalesce, forming south of Durango a series of sharp-crested hogbacks trending east and west. The northern fold has everywhere upturned the pre-Laramie strata. The fold dies out in the Mesa Verde, but becomes pronounced again to the south, where these rocks are sharply upturned toward the east in the "Great Hogback," near Jewett, and farther south.

On La Plata River near Hesperus the dip of the pre-Laramie is 5° to 10°; but farther south the rocks flatten and descend at an angle only slightly greater than the grade of the river. At a point just north of Pendleton, N. Mex., there is a second monocline which Holmes [a] has called the San Juan fold. A change of dip occurs here, and the Laramie rocks, dipping 10° to 20° SE., cross the river

[a] Holmes, W. H., Geology of the San Juan district: Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, pp. 237-276.

in a low northward-facing hogback. East of McDermott Arroyo the San Juan fold continues northeastward, forming the Basin Mountains, which at longitude 108° swing eastward and cross Animas River at Carbon Junction, where this fold merges with the northern fold. Southwest of La Plata River, trending parallel to the Great Hogback, the San Juan fold presents a westward-facing escarpment of Laramie rocks, which form the eastern boundary of the Vegas, or Meadows. The fold, coalescing with the Great Hogback, crosses San Juan River at Fruitland, the Laramie strata dipping at an angle of less than 2° and flattening toward the south. At Cottonwood Creek they are practically horizontal.

The disturbance of the strata in the northern part of the field after the close of the Cretaceous was followed by a period of quiet, during which a part, or possibly all, of the Tertiary sediments were deposited. Then came a second uplift in the San Juan Mountain region, accompanied and perhaps caused by igneous intrusion. This disturbance resulted in a farther southward tilting of the Cretaceous rocks in the extreme northern part of the area and a consequent tilting of the overlying Tertiary beds. As can be seen from the Animas River structure section (Pl. XXIII), neither of these disturbances affected the beds for any great distance away from the mountains. The folds are sharp, but the strata flatten within a very short distance to the south.

South of San Juan River and north of Zuni Basin the disturbances of the strata are comparatively simple. After the close of Cretaceous time, folding of the monoclinal type occurred, affecting only the pre-Laramie sediments to any considerable degree. The result of this disturbance is shown in the southward extension of the Great Hogback, which, trending west of south from San Juan River, presents a succession of low serrated peaks and sharp-crested ridges to the point where, near Crozier, it disappears under the flat-lying Tertiary sediments of the Choiskai Mountains. This monocline involves the strata of the coal-bearing Mesaverde formation and the upper part of the Mancos. It presents a westward-facing escarpment throughout its length, the strata showing eastward dips of 35° to 50°.

After the deposition of the Tertiary sediments, eruptions of tuffaceous lava and later intrusions of biotitic monchiquite dikes occurred in the region south of San Juan River. Ship Rock, Bennett, and Ford peaks, the dikes radiating therefrom, and the lava flow capping the northern portion of the Choiskai Mountains are results of this volcanic outburst.

The structure of Zuni Basin has already been ascribed to the crumpling of the upturned rim of the major basin. Apparently all of the folding occurred just after the close of Cretaceous time. On the west the basin is bounded by the Defiance monocline, which is the southward extension of the Great Hogback after it reappears east

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of Fort Defiance, Ariz., from beneath the Tertiary covering in the Choiskai Mountains. This fold extends southward and is crossed by the Atchison, Topeka and Santa Fe Railway west of Manuelito; thence it trends in a southerly direction to the latitude of Zuni village, where its axis lies about 2 miles east of Blackrock. On the north the rocks dip steeply eastward, but south of Manuelito the strata flatten until south of Zuni the dip is very low.

As will be seen by reference to the north-south structure section through the basin (Pl. XXIII), the rocks north of Salt Lake dip northward at a very low angle to a fault near the latitude of Ojo Caliente. This fault has an upthrust on the north which at a point about a mile south of Ojo Caliente brings Carboniferous (Aubrey?) limestone in contact with the upper part of the Mancos. The strike of the fault is south of east, but at a distance of a few miles it is obscured beneath the great lava flow that covers a wide area south of Tarche. The Nutria monocline of Gilbert[a] bounds the Zuni Basin on the east. The westward dip of the upturned beds reaches a maximum of 70° near Nutria, but averages about 45° between Gallup and Nutria. Toward the south the strata of the monocline flatten rapidly until at Ramah and beyond the dip is less than 10°. North from the Santa Fe Railway east of Gallup the dip gradually diminishes and its direction changes to northwest. Finally the rocks dip to the north at an angle not exceeding 5°, and their gently upturned edges form the rim of the major basin to and beyond the eastern limit of the area under discussion. The structure of the interior of the basin is shown by the section drawn from Durango southward through Putnam (Pl. XXIII).

Careful lithologic and paleontologic examination of the strata failed to reveal any displacement along either the Great Hogback, its southern extension, the Defiance monocline, or the Nutria monocline.[b] At short distances away from these sharp flexures the strata flatten; hence the basins between the folds are shallow.

In Zuni Basin a period of remarkable volcanic activity followed at apparently a considerable interval after the deposition of the Tertiary sediments. From the eruptive centers, most of them probably some distance east of the coal field, great flows of basic lava were poured westward, covering, as can be seen by a reference to the map (Pl. XXII, p. 376), a large area in this basin. Gilbert[c] describes in detail the remarkable extent of this lava flow, of which only a comparatively small tract lies within the boundaries of the coal field.

[a] Gilbert, G. K., U. S. Geog. Survey W. 100th Mer., vol. 3, 1875, pp. 550-553.

[b] Both Newberry and Dutton, in reports already cited, deduce the existence of a fault of considerable downthrow on the west immediately west of the axis of the abruptly flexed beds in the Nutria monocline. Gilbert and Howell, in vol. 3 of the Wheeler Survey reports, deny the existence of such a fault.

[c] Op. cit., p. 525.

COAL.

COAL-BEARING FORMATIONS.

The coal beds of this field lie at various horizons. In the vicinity of Durango the best coal occurs in the Mesaverde formation. Coal was mined from the thicker Laramie beds some years ago at what is known as the La Plata mine, southeast of Durango, and at the Carbonero mine, on the Denver and Rio Grande Railroad below Durango in Animas Valley. When it was found, however, that the Laramie coals were so much inferior to those of the Mesaverde that they could not compete with them in the market the Laramie mines were abandoned.

On La Plata River near Pendleton and on San Juan River at Fruitland coal has been mined for a number of years for local consumption and to supply the market at Aztec and Farmington. The coal is the Carbonero bed of the Laramie formation. East of Fort Defiance, Ariz., and in New Mexico, coal has been mined since 1894 from beds near the base of the Mesaverde formation:

In the vicinity of Gallup the coals mined are contained in the Mesaverde; they are good grade subbituminous coals and occur in beds up to 8½ feet in thickness. Between Nutria and Blackrock coal has been mined for the last three or four years from two beds about 40 inches thick, occurring in the upper part of the Mancos formation. The coal is a good grade of subbituminous, and is used successfully as fuel at the Indian school at Blackrock and in the construction of a large dam at that place.

At nearly every locality where the Dakota formation outcrops within the area, coal is present. Although generally of poor quality, it becomes locally high-grade bituminous. North of Mancos it is mined on a small scale.

DETAILED DESCRIPTIONS.

For convenience in description, the area under discussion is divided into five districts, which will be described in order of location from north to south.

DURANGO-MESA VERDE DISTRICT.

The Durango-Mesa Verde district includes the Colorado portion of the field, extending westward from Florida River. The largest town in this district is Durango, a county seat having a population of about 4,000. Other towns are Porter, Hesperus, Mancos, and Cortez. The Denver and Rio Grande Railroad furnishes eastern and northern outlets for the district, and its branch line down Animas Valley connects Durango with the rich San Juan Valley country. The Rio Grande Southern Railway connects Durango, by way of Porter, Hesperus, and Mancos, with the mining region about Rico and Telluride.

The coals of this district occur in three formations—the Mesaverde, Laramie, and Dakota, named in the order of the value of their coals. The Dakota coal bed is nearly everywhere dirty and generally is not mined where other coal beds are available. Its maximum observed thickness is about 7 feet, including bony and shaly partings.

The Mesaverde coal is commercially the most valuable, though not the thickest in the district. The maximum observed thickness is 7 feet, but the average for the workable beds is much less than this, being probably about 5 feet. The coal is of excellent quality and in the vicinity of Durango and Porter makes good coke, which is extensively used in the smelters of the region.

The Laramie coal beds are the largest in the district, the maximum observed thickness of an individual bed being about 80 feet, including a considerable number of thin partings in its upper part. The coals are not of so high grade as those of the Mesaverde formation and can not at present compete with them. They are, however, good bituminous coals and undoubtedly will be of great value under better conditions of transportation and market.

The coal beds outcropping between Florida River and the town of Mancos will be given only a cursory treatment here.[a]

Four workable Laramie coal beds occur at the abandoned La Plata mine, 3 miles southeast of Durango. Openings were made in three of the coal beds, which exposed the following section:[b]

Section of coal-bearing strata at La Plata mine, 3 miles southeast of Durango.

	Ft.	In.
Upper or Peacock bed:		
Shale roof.		
Coal	1	8
Sandstone, shaly		2–4
Coal	3	2
Coal, bony		3
Coal		7
Shale		4
Coal	2	7
Fire clay.		
Shale and sandstone	75	
Sandstone, brown	3	
Jumbo bed:		
Coal, with many shale and bone partings	20	
Sandstone and shale	50	
Fairmont bed:		
Coal, with bands of shale and bony coal	15	
Shale and sandstone	100	
Lower bed:		
Coal	4	
	275	10

[a] For a detailed report on this area, see paper by Joseph A. Taff, pp. 321-337 of this bulletin.

[b] At the time of the writer's visit the Fairmont bed had been burning for more than two years, and the entry on the Jumbo bed was filled with water, hence accuracy of measurement was impossible.

Most of the output of the La Plata mine was from the Fairmont bed, which contains an upper bench of coal about 4 feet thick that is free from impurities. The strata dip southeastward at an angle of 28°.

At Carbon Junction, near Animas River, all these beds coalesce, forming the Carbonero bed, which, including several thin bony and shaly partings, attains a total thickness of nearly 100 feet. It is doubtful if more than one-third of this bed can be mined because of the numerous partings. Several benches of clean coal up to 5 feet in thickness are, however, present in this mammoth bed, and probably can be worked economically.

Farther west, at Indian Creek, the Carbonero bed appears to split into several beds as at the La Plata mine. The same condition, but to a less extent, was observed east of "Burned Timber," near the Hesperus–Laplata wagon road. One of the beds is 20 feet thick, including two thin unimportant partings.

The Peacock bed of the Mesaverde formation is mined by the Calumet Fuel Company on Perrine Peak west of Durango. The coal is of excellent quality, and produces a good grade of coke. The area of the present workings is about 12 acres. The following section, measured 1,200 feet in the mine, gives a good idea of the condition of the coal bed:

Section of coal bed in Perrine Peak mine, west of Durango.

	Ft.	in.
Shale roof.		
Coal	6	10¾
Shale		6–8
Coal		3½
Shale floor (?).		
	7	9¼

The coal bed mined at Perrine Peak is locally considered to be the same as the bed mined at Hesperus and the upper bed mined at Porter. Though this coal obtained as far west as Porter cokes in the ordinary beehive oven, tests at Hesperus have not yielded satisfactory results.

The length of the main entry of the Hesperus mine is about 4,800 feet in the direction of the dip, which is to the south at an average angle of 7°. The bed ranges in thickness from 4 feet 10 inches to 6 feet 6 inches and locally a thin parting is present. The following section was measured where the sample was taken for analysis:

Section of coal bed in Hesperus mine.

	Ft.	in.
Coal	3	10
Bone		¼
Coal	1	6
Coal, bony, variable	1	3
Sandstone floor.		
	6	7¼

Along the outcrop of the Mesaverde formation numerous test openings have been made which prove the generally uniform thickness and good character of the coal beds of this formation. Between Spring and Deadman gulches a natural exposure shows the presence of four beds, one of which is 4 feet thick.

In Alkali Gulch on the Crawford ranch a prospect tunnel driven into the east bluff shows one of the Mesaverde coals measuring about 5 feet, which appears to be of the same character as the Hesperus bed. The rocks in Alkali Gulch have a low dip to the south.

A Mesaverde coal bed has recently been opened on the Wiltsey farm in Hay Gulch, by an entry driven on the bed for a distance of 150 feet. A section of the coal is as follows:

Section of coal bed in Wiltsey prospect tunnel.

	Ft.	in.
Sandstone.		
Coal	2	
Coal, bony		4
Coal	4	4
Shale, bituminous.		
	6	8

This coal resembles the Hesperus coal and probably is of equally good quality. The strata in Hay Gulch have a low southeasterly dip, thus making it possible for the coal beds of the Mesaverde to be reached at comparatively slight depth over a wide area lying to the southeast, embracing the greater part of Fort Lewis Mesa.

Seven miles north of Mancos, at the Haller mine, an entry has recently been driven for about 55 feet on a Dakota coal bed. The coal is reported to be a coking coal and to work well in the forge. The following section is exposed in the tunnel:

Section of coal bed in the Haller mine, 7 miles north of Mancos.

	Ft.	in.
Coal		10+
Shale	2	6
Coal	1	3
Shale		6
Coal	1	6
Coal, bony		8
Coal	1	5
Sandstone		½
Coal	1	3
Bony coal floor.		
	9	11½

The same bed has been mined on the east branch of Mud Creek 3½ miles northwest of Mancos. An entry has been driven here for 220 feet, and from it the coal bed has been worked for an equal distance on either side. The coal measures 4 feet 3 inches, including two bony partings of 1 inch each. The roof is bony coal and the floor fire clay. The quality of the coal is apparently the same as at the Haller mine.

MESA VERDE REGION.

South, southeast, and southwest of Mancos the Mesaverde coal beds are exposed in the escarpments of Mesa Verde. This mesa is a high table-land bounded on the north, west, and south by perpendicular cliffs. Its character is shown best by the cross sections (Pl. XXIII, p. 382). Two escarpments formed of massive sandstones of the Mesaverde, underlain by soft clay shale, are prominent features of the mesa cliffs. The lower one forms the base and the upper the top of the Mesaverde formation; they were called by Holmes[a] the Lower Escarpment and Upper Escarpment sandstones.

In Mesa Verde two workable coals, the Upper and Spencer beds, are separated by about 300 feet of shales and sandstones, with several thin coal beds. The Spencer bed outcrops near the mouth of Mancos Canyon, and the Upper bed appears still farther south.

The Wood and Spencer mines are located southeast of the town of Mancos, in sec. 36, T. 36 N., R. 13 W., and sec. 2, T. 35 N., R. 13 W., respectively. At the Spencer mine coal has been taken out for the local market for eighteen years. The coal is 3 feet thick and of excellent quality. The roof is sandstone and the floor shale. About 50 feet below the Spencer is another good coal bed 38 inches thick. The Spencer bed is also worked at the Wood mine, which has been recently opened. A section of the coal bed at this place is as follows:

Section of coal bed in Wood mine, southeast of Mancos.

	Ft.	in.
Shale.		
Coal	1	4
Shale, variable		½-5
Coal	3	
Coal, bony		6
Sandstone, friable.		
	5	1

The rocks at both the Spencer and the Wood mines dip about 3½° S. 30° E. The coal is of excellent quality.

In the following descriptions the numbers refer to localities designated by corresponding numbers on the map (Pl. XXII, p. 376).

No. 18: In sec. 35, T. 35 N., R. 14 W., Fred. Armstrong and others several years ago prospected the Spencer bed, exposing 4½ to 5 feet of excellent coal. The floor is massive sandstone and the roof friable sandy shale. East of the canyon, in sec. 19, T. 35 N., R. 13 W., the same coal bed is reported to lie practically on the surface, and to have a thickness of more than 3 feet.

Nos. 19 and 20: In sec. 19, T. 35 N., R. 14 W., the Spencer bed outcrops in the head of Moccasin Canyon. The Upper bed shows 2½ miles farther south. At neither of these points were the beds examined in detail.

[a] Holmes, W. H., Geology of the San Juan district: Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, p. 254.

No. 21: The Todd mine, in sec. 28, T. 35 N., R. 14 W., has recently been opened on the Spencer bed by Samuel Todd and John Bolster. The rocks dip southward at an angle of 7°. The coal bed ranges in thickness from 28 to 30 inches and lies between beds of firm shale. The coal burns well, leaving a very small amount of white ash. About 300 feet above the Spencer the Upper bed outcrops in two benches, separated by 3 feet of shale, and is underlain by hard carbonaceous shale. The top and bottom benches measure, respectively, 22 and 33 inches. Its quality appears to be poorer than that of the coal at the Wood and Spencer mines.

In the westward-facing escarpment of Mesa Verde, coal beds occur at intervals throughout 400 feet of strata lying between the upper and lower sandstones.

No. 22: In sec. 28, T. 35 N., R. 16 W., the lower or Spencer bed is less than 30 inches thick. The Upper bed is split by a parting into two benches. A natural exposure shows the following section between beds of hard clay shale:

Section of coal bed at location No. 22.

	Ft.	in.
Coal	2	4
Coal, bony		6
Shale	2	1
Coal	1	3
	6	2

The rocks dip 7° S. The coal is hard, clean, and apparently of good quality.

No. 23: East of Burnham's ranch, near the southern line of the Southern Ute Indian Reservation, the coal-bearing rocks are not well exposed, but the Upper bed is apparently present and possibly thicker than at location No. 22.

No. 24: In the mesa cliff 2½ miles east of Ute Agency, in sec. 1, T. 33 N., R. 17 W., several coal beds show in outcrop, but only one of these, the Upper bed, is thick enough to be of economic value. It lies between shale beds, has a thickness of 50 inches, and consists of hard, clean coal.

No. 25: In the west wall of Mancos Canyon, in sec. 15, T. 34 N., R. 14 W., the Spencer bed occurs in two benches of 20 inches each, separated by 12 inches of bony coal. The roof is hard, massive sandstone, and the floor shale. The presence of the Upper bed was not determined at this location.

No. 26: One-half mile above the mouth of Fort Lewis Creek, in sec. 31, T. 34 N., R. 14 W., near the level of the canyon floor, the Spencer bed outcrops, showing 4 feet of clean, hard coal. The floor is bony coal and the roof clay shale. The rocks dip south at an angle of 5°.

No. 27: In Cliff Canyon natural exposures in the canyon walls at two points show the general uniformity in occurrence of the Upper and Spencer beds throughout the mesa. Near the mouth of Cliff Canyon, in sec. 3, T. 33 N., R. 15 W., the entire thickness of coal-bearing rocks measures only about 200 feet. The Upper bed shows 44 inches of hard, clean coal. The Spencer bed is represented by 14 inches of coal lying between beds of shale. Between the Upper and Spencer beds two of the intermediate thin beds of other localities in the mesa have locally thickened, one to 20, the other to 30, inches of good coal. The rocks here lie practically flat.

No. 28: Between Spruce Tree House and Spring House forks of Navajo Canyon only the Upper bed is exposed, the Spencer lying at a lower level than the canyon floor. The exposed bed is 5 feet thick, but has a 1-foot shale parting in the middle, which is easily separable from the coal. The roof and floor are hard, firm, clay shale.

No. 29: In Ute Canyon 150 feet of coal-bearing strata are exposed, which includes both the Spencer and Upper as well as several intermediate coal beds that are locally of economic importance. The following section is exposed in the canyon walls:

Section in Ute Canyon.

	Ft.	in.
Shale.		
Coal	1	
Shale, black	4	
Coal	1	
Shale	20	
Coal, Upper	4	9
Shale and thin sandstone	30	
Coal	2	
Shale and thin sandstone	25	
Coal	3	6
Shale and thin sandstone	25	
Coal	4	
Shale (principally)	100	
Coal, Spencer	2	
	222	3

No. 30: In the south cliff of Mancos Canyon, just above the mouth of Navajo Canyon, the following section is exposed, the lowest coal bed of which lies about 400 feet above river level:

Section of coal-bearing rocks at location No. 30, in Mancos Canyon.

	Ft.	in.
Upper sandstone	250	
Shale with coal streaks	30	
Coal, free from partings	3	10
Shale, black	35	
Coal	2	
Shale, black	5	
Sandstone	12	
Shale, black	5	

	Ft.	in.
Coal		6
Shale, black	6	
Coal	1	2
Shale, black	15	
Coal	1	
Shale, black	10	
Coal	1	8
Sandstone		1
Coal	1	4
Shale, black	45	
Coal	1	10
	426	5

Several of the coal beds of the above section are accessible for mining and are of workable thickness and quality.

No. 31: About 1½ miles up the canyon from the locality just described an intrusive body of basic lamprophyre with radiating dikes of the same material occurs in the south canyon wall. Just below this igneous rock a bed of excellent coal outcrops about 20 feet above the river level. The bed is 47 inches thick, without partings, and has a firm shale roof and bony coal floor. It is easily accessible and lies practically horizontal.

No. 32: The subjoined section is exposed in the cliff about 3 miles up Soda Spring Canyon. The section was measured one-half mile above a lamprophyric dike, which, trending north and south, cuts across the canyon, and the same distance below an excellent soda spring.

Section of coal-bearing rocks in Soda Spring Canyon at location No. 32.

	Ft.	in.
Sandstone		6
Coal	1	11
Shale	40	
Shale, carbonaceous	6	
Coal	1	3
Shale, carbonaceous	4	
Coal		10
Shale		4
Coal		6
Shale	20	
Sandstone and shale	14	
Coal	2	2
Coal, bony		1
Coal		5
Sandstone and shale	15	
Coal, variable, bony streak in middle 1 inch thick	4	7
Sandstone and shale	14	
Lenticular band of "Black band" iron ore	1	
Shale	6	

	Ft.	in.
Coal	1	4
Shale, carbonaceous	8	
Coal	2	1
Sandstone		1
Coal	1	8
Shale, carbonaceous	1	6
Coal, dirty	1	2
Shale, carbonaceous		4
Coal	1	2
Fire clay and carbonaceous shale	6	
Coal	1	2
Fire clay	5	
Shale and sandstone	20	
Shale	1	
Coal	2	11
	186	

No. 33: Several coal beds similar in thickness and quality were noted about 2 miles above the exposure just described.

No. 34: Eight miles above the crossing of the Ship Rock-Cortez wagon road the Upper coal bed of the Mesaverde occurs 1,200 feet above river level in the south wall of Mancos Canyon. It is 67 inches thick, is clear of partings, and has a firm shale roof and floor.

Workable coal beds representing the Spencer, Upper, and intermediate beds have been prospected or examined in natural exposures at many other points within Mesa Verde, showing conclusively that their lateral extent, thickness, and quality are more or less uniform throughout the area of the mesa.

LAPLATA-FRUITLAND DISTRICT.

The Laplata-Fruitland district, so named from towns in the area, is located wholly in northwestern New Mexico, north of San Juan River.

The Great Hogback, composed of the upturned Mesaverde formation, rises northward from San Juan River to a height of 500 feet and extends in two parallel unbroken serrated crest lines to a point about midway between Baldwin's store and the State line, where the beds flatten and the fold blends into Mesa Verde. The eastern crest is formed by the upper, and the western, subordinate ridge by the lower sandstone. The coal-bearing strata outcrop in a sag between these ridges. The dip at the river is 40°, but decreases rapidly toward the north, and as a consequence the ridges become more and more separated until the sag develops into a considerable valley. The dip finally falls off to 5° and less, and the various members of the hogback connect with the corresponding members of Mesa Verde.

West of the hogback the Mancos shale, and still farther west the Dakota sandstone, which outcrops just east of the mouth of Mancos River, rise above river level.

East of the Great Hogback a wide, rolling, valley country, the Vegas or Meadows, extends to a northwestward-facing escarpment, the San Juan fold of Holmes, formed of the Laramie sandstones and shales. This valley has been eroded in the nonresistant Lewis shale. The Laramie escarpment presents where it is crossed by La Plata River and for some distance farther south an abrupt northwest face. As the dip of the strata comprising this monocline decreases to the south the escarpment is broken here and there into a series of detached table-lands, whose surfaces slope gently in the direction of the dip. East of this monocline the rocks are chiefly flat-lying marls, capped by sandstones and conglomerates, in which the numerous small tributaries of Animas and La Plata rivers have encountered little resistance to their downward cutting, so that the resulting topography is of the badlands type.

The coals represented in the Laplata-Fruitland district occur in the Mesaverde, Laramie, and Dakota formations. The Dakota coal is mined on San Juan River, a few miles below Ship Rock, for use in the heating plant of the Government Indian school at that town. It is reported to be dirty and not a very satisfactory fuel. A new mine has been opened on the 4½-foot Mesaverde coal bed exposed in the Great Hogback near Jewett, and the coal found to be of excellent quality.

The Mesaverde coals in this district are similar in thickness and quality to those exposed in Mesa Verde. They are not mined at present, but have been prospected and their natural outcrops examined in many places.

The Carbonero bed of the Laramie formation is mined on a small scale in the vicinity of Pendleton on La Plata River and near Fruitland on the San Juan, some of the coal being hauled by wagon to Aztec, Farmington, and other small neighboring towns. The maximum observed thickness of this bed is nearly 50 feet. Other coals are present in the Laramie, both above and below this bed, but generally they are poorer in quality and thinner. The quality of the Laramie coal in this district is better than it is in the vicinity of Durango.

Short prospect entries were driven on each of the three upper Mesaverde coal beds that outcrop in Barker Arroyo, in secs. 5 and 6, T. 22 N., R. 13 W., in the summer of 1905, under the direction of C. W. Fisherdick, of Laplata, for the Arizona and Colorado Railroad. The upper coal varies greatly in the six prospect entries driven on it. The extremes are shown in the subjoined sections, measured in prospects about 1 mile apart on the middle and south branches of the arroyo, respectively. The strata dip at an angle of 15° to 20° S. 70° E.

Sections of upper bed in Fisherdick prospect, Barker Arroyo.

LOCATION No. 35.	Ft.	in.	LOCATION No. 36.	Ft.	in.
Sandstone roof.			Sandy shale roof.		
Shale		2	Coal		8
Coal	3	8	Shale		1¼
Sandstone floor.			Coal	4	2
	3	10	Shale floor.		
				4	11¼

The middle one of the three Mesaverde beds is separated from the upper by 85 feet of sandstone and shale. It was mined from 1882 to 1890 in the middle branch of Barker Arroyo (No. 37), and supplied coal for the neighborhood. This mine, known as the Hepler, was abandoned because a fault was encountered in the workings and a bony coal parting 6 inches thick had gradually come in near the middle of the bed. The coal is hard and apparently of good quality, and at the breast of the 100-foot entry still remains hard and unweathered. The bed dips at an angle of 16° S. 70° E., and presents the following section in an open prospect in the north branch of Barker Arroyo:

Section of middle Mesaverde coal bed in north branch of Barker Arroyo, at location No. 38.

	Ft.	in.
Shale, sandy.		
Coal	1	8½
Coal, bony and shale		11
Coal	3	4
Brown carbonaceous shale.		
	5	11½

At a distance of 75 feet below the middle bed the lower coal of the Mesaverde section is exposed as follows in the south branch of Barker Arroyo:

Section of lower Mesaverda coal beds in south branch of Barker Arroyo at location No. 39.

	Ft.	in.
Shale, sandy.		
Coal	2	
Shale, carbonaceous	10	
Coal	1	3
Shale, carbonaceous	3	9
Coal	1	10
Covered.		
	18	10

The strata dip at an angle of 15° S. 15° E.

All of the Mesaverde coal-bearing section in Barker Arroyo immediately underlies the upper sandstone, which is here more than 250 feet thick. The overlying Lewis shale, having the same character as in the Durango–Mesa Verde district, is 2,300 feet thick. It is believed that this represents a local thickening at the crest of the fold, inasmuch as north of the State line and on San Juan River the same formation is only about 1,600 feet thick.

The basal Laramie sandstone, which lies between the Laramie coal-bearing rocks and the Lewis shale, includes some thin intercalated shales and measures 180 feet as exposed in Barker Arroyo. There are three coal beds in the Laramie, the middle or Carbonero bed being the only one mined in the district. The lower and upper beds are generally thin and dirty, and are separated from the Carbonero bed by 60 and 250 feet, respectively, of shale and sandstone.

No. 40: An opening in the Pruitt pasture, known as the Pruitt mine, is located about 25 feet north of the State line in sec. 23, T. 32 N., R. 12 W. This mine is a chamber 25 feet wide, 100 feet long, and high enough for wagons to enter and load direct from the working face. The bed is 36 feet thick, but only 10 feet is mined. It is a good-grade bituminous coal. A section of the entire bed is as follows:

Section of Carbonero bed at Pruitt mine, location No. 40.

		Ft.	In.
	Shale, brown, carbonaceous.		
	Coal	1	
	Sandstone		¼
	Coal	1	6
	Sandstone		¼
	Coal	3	6
	Shale		½
	Coal	1	6
	Coal, bony		1
	Coal	2	
	Sandstone		1
	Coal	2	
	Sandstone		¼
	Coal	1	6
	Shale		2
	Coal	5	
	"Rash"		2
	Coal	2	
	Coal, sandy, bony		1
Part mined.	Coal		10
	Bone		¼
	Coal	1	
	Coal, sandy, bony		4
	Coal		7
	Coal, sandy, bony		1
	Coal, sampled	4	10
	"Rash"		10
	Coal	1	7
	Shale, drab clay		6
	Coal	5	
		36	3½

No. 41: The O'Brien mine, located a short distance east, and the Greer mine, a short distance west of La Plata River, in sec. 15, T. 32 N., R. 13 W., are also on the Carbonero bed. These mines were

closed after they had been taken over two or three years ago by the Phelps-Dodge Mining and Smelting Company. The coal is similar in section and quality to the bed at the Pruitt mine. The rocks dip at an angle of 15° S. 10° E. At the O'Brien mine a slope was driven on the coal for a distance of 800 feet to a point where considerable water and gas were encountered. At the Greer mine a heading was driven for about 350 feet with the rise of the coal, and rooms were worked out from cross entries driven for 200 feet on either side of the main entry. The coal is reported to have excellent steaming but no coking qualities. These mines supplied coal for the New Mexico towns in Animas Valley as well as for the local trade.

Nos. 42 and 43: The Thomas and the Jones mines, located respectively in secs. 22 and 21, T. 32 N., R. 13 W., at present supply practically all of the local and a part of the Aztec and Farmington trade. Both mines are in the Carbonero bed, but their workings are not yet very extensive. The coal section is similar in both of these mines, and roughly corresponds to that exposed at the Pruitt mine. The Thomas mine (No. 42) was opened in 1895, by an entry driven for 275 feet on the strike of the bed, which dips at an angle of 20° S. 53° E. The coal is bituminous in quality. A section of the part of the bed mined is as follows:

Section of the part of the Carbonero bed mined in the Thomas mine, at location No. 42.

	Ft.	in.
Sandstone.		
Coal	4	10
Fire clay		6
Coal	4	6
Sandstone floor.		
	9	10

A coal bed 3½ to 4 feet thick, locally known as the Peacock bed, occurs near the Thomas mine, 250 feet stratigraphically above the Carbonero bed. It has been prospected and appears to be of excellent quality, but wherever exposed to the southwest or northwest it is badly split up by partings.

No. 44: At the Walker mine, about 4 miles south of west from Young's ranch, a slope has been driven for a distance of 100 feet in the Carbonero bed on a dip of 5° S. 65° E. A section of the part of the bed mined is as follows:

Section of Carbonero bed at Walker mine, at location No. 44.

	Ft.	in.
Shale, hard, clay.		
Coal	3	4
Sandstone		1
Coal		9
Sandstone		1½
Coal	2	3
Shale, carbonaceous	2	
Total coal bed	6	6½

No. 45: In sec. 12, T. 31 N., R. 14 W., just west of the eastern boundary line of the Ute reservation, the following section of one of the lower Mesaverde coals is exposed in a small side canyon of Barker Arroyo:

Section of Mesaverde coal bed exposed at location No. 45.

	Ft.	in.
Shale, brown.		
Coal		3
Coal, bony, and shale		5
Coal	6	8
Coal, bony.		
	7	4

The coal bed dips at an angle of 10° SE. It is fairly hard and apparently good bituminous coal.

No. 46: About 5 miles east of north from Young's ranch, in the Ute reservation, the following section is exposed in the canyon walls of a tributary of Coal Creek:

Section of upper Mesaverde coal bed at location No. 46.

	Ft.	in.
Shale roof.		
Coal	2	
Coal, bony		4
Coal	3	
Shale floor.		
	5	4

This bed lies practically horizontal, about 50 feet below the base of the upper sandstone. It outcrops just above the level of the canyon floor, is persistent in thickness and of good quality, and offers a considerable workable area.

No. 47: About 1 mile northeast of Navajo Spring, the upper bed outcrops in the wall of a box canyon at the head of Coal Creek. This bed is about 40 inches thick, lies horizontal, 6 feet below the upper sandstone, and has a firm shale floor and roof. Careful search failed to reveal the existence in workable thickness of any of the other Mesaverde coal beds.

No. 48: In the Great Hogback, 3 miles west of the Walker mine, just below the upper sandstone of the Mesaverde formation, the following coal section is exposed:

Section of coal beds exposed in Great Hogback, at location No. 48.

	Ft.	in.
Sandstone, massive	20+	
Coal	4	4
Shale	10	
Sandstone and shale	40	
Coal	4	8
Shale floor.		
	79	

The strata at this locality dip 15° S. 30° E., and the same beds are exposed at numerous places in each direction along the strike, their thickness and quality being generally uniform.

No. 49: Where San Juan River cuts the Great Hogback at Baldwin's store, the following section of the coal-bearing Mesaverde was measured north of the river:

Section of coal bed exposed in Great Hogback west of Baldwin's store, at location No. 49.

	Ft.	in.
Clay shale.		
Coal	1	8
Shale and shaly sandstone with fossil plants	4	
Coal		6–8
Shale and sandstone	3	
Clay shale	2	
Coal	6	2
Shale	1	
Coal		6
	18	11

Between this section and the upper sandstone is a mass of sandstones and shales about 500 feet thick, containing in the upper part a number of coal beds that may be correlated with the coal beds at location No. 48. Their thicknesses were not determined. The strata dip eastward at an angle of 40°.

No. 50: At the Thurling mine (Bruce mine), in sec. 27, T. 30 N., R. 15 W., between Young's ranch and Jewett, the Carbonero bed, 23 feet thick, was formerly worked, and it is practically all good coal.

No. 51: The Stephens mine (Young mine), in sec. 4, T. 29 N., R. 15 W., was opened several years ago near the Fruitland-Jewett road, 1½ miles northwest of Fruitland. It furnishes the coal used at Fruitland and Jewett, and a considerable quantity is hauled from the mine by wagon to Farmington and the surrounding country. It is opened by a drift 100 feet long, running N. 30° W. on the bed, which lies nearly horizontal. The total thickness of the bed is about 16 feet, including several thin partings in its upper part. The section is as follows:

Section of Carbonero bed at Stephens mine near Fruitland, at location No. 51.

	Ft.	in.
Shale.		
Coal	4	
Coal, bony		6
Coal	5	
Slate, draw		2
Coal	2	
Slate, draw		2½
Coal (mined)	5	
Fire clay.		
	16	10½

Only the lower bench is worked. The quality of the coal is approximately the same as at the Pruitt, Jones, and Thomas mines.

RIO CHACO DISTRICT.

The Rio Chaco district includes that part of the field which lies south of San Juan River and north of the latitude of Fort Defiance, Ariz. Trending southward from the point where it crosses San Juan River, the Great Hogback forms a prominent series of detached, serrated, short ridges along the west border of the field until it disappears beneath the horizontal Tertiary strata of the Choiskai Mountains.

The coal-bearing formations in the Rio Chaco district are the Dakota, Mesaverde, and Laramie. The Dakota coal was not examined nor the formation mapped in this district.

The Mesaverde coal beds vary more in thickness and number than in the northern districts, and the barren rocks between the horizons of the Upper and Spencer beds of Mesa Verde are thicker. As may be seen from the map (Pl. XXII, p. 376), this formation covers a considerable area south of San Juan River, and forms the Great Hogback ridge. This fold becomes less pronounced in the direction of Bennett Peak and the strike of the upper beds swings eastward, paralleling Rio Chaco. The upper standstone forms the walls of Chaco Canyon to Pueblo Alto, above which point the stream has not cut its channel through it. The lower sandstone and along with it the lower part of the coal-bearing rocks continue their southerly trend until, dipping steeply, they disappear near Crozier beneath the unconformable Tertiary strata of the Choiskai Mountains.

The Laramie coal beds, where they are not concealed by unconformable Puerco marl, are of considerable thickness, but they do not compare with the Carbonero bed. It is not possible to correlate the individual coal beds with the beds north of San Juan River, because the Puerco marl prevents their being traced continuously through the district. No openings have been made on any of these coal beds, hence no samples were collected for analysis; but they are apparently of as good grade as the Carbonero bed at Fruitland and are freer from visible impurities.

No. 52: Where Rio Chaco has cut its channel through the Great Hogback about 2 miles south of Baldwin's store, a coal bed outcrops just above the lower sandstone of the Mesaverde. The strata here dip eastward at an angle of 40°. A section of the coal bed follows:

Section of Mesaverde coal bed in Rio Chaco Gap, at location No. 52.

	Ft.	in.
Sandstone, gray.		
Shale, brown, carbonaceous	2	
Coal, clear	5	1
Shale, brown, carbonaceous	3	
Sandstone.		

No. 53: Two miles farther south the following section of a coal bed in the Mesaverde is exposed in the Great Hogback:

Section of Mesaverde coal bed at location No. 53.

	Ft.	in.
Shale, dark, bituminous	10	
Coal	1	2
Shale, dark	5	
Coal	2	11
Shale, brown, carbonaceous.		

This section occurs just below the upper sandstone about 800 feet above the coal bed of location No. 52, described above.

No. 54: Southwest of Fruitland a coal bed is exposed in nearly horizontal Laramie strata with the following section:

Section of Laramie coal bed near Fruitland, at location No. 54.

	Ft.	in.
Clay, shale, dark.		
Coal	4	3
Shale, brown, carbonaceous		4
Coal		5
Shale, brown, carbonaceous.		
	5	

Between this latitude and Cottonwood Arroyo the Laramie coal beds have generally been burned near the surface and no idea of their thickness could be obtained. Six feet of coal, very resinous and breaking with a fracture similar to cannel coal, occurs in Cottonwood Arroyo at location No. 55. The coal bed dips eastward at an angle of 4°.

No. 56: About 4 miles south of the point where Cottonwood Arroyo crosses the Fruitland-Gallup road, 2 miles east of Rio Chaco, the following section of Laramie coal-bearing rocks is exposed about 60 feet stratigraphically above the basal sandstone:

Section of Laramie coal-bearing rocks at location No. 56.

	Ft.	in.
Sandstone, brown, shaly	8	
Shale, drab	3	
Shale, dark	1	
Coal, bony	2	7
Shale, brown, carbonaceous	7	
Coal	7	4
Shale, brown, carbonaceous.		
	28	11

The strata have a low easterly dip and the coal is clean and firm. In the bank of an arroyo about 2 miles northeast of this place, at location No. 57, the same coal bed was observed in like thickness and purity, hence it is probable that there is a considerable area of workable coal between these points.

No. 58: Just south of a tuffaceous lava peak protruding from the Great Hogback west of the mouth of Cottonwood Arroyo three coal beds occur below the upper sandstone of the Mesaverde. From the top downward the beds show, respectively, 7, 4, and 4 feet of clear, hard coal. The strata here dip at an angle of 30° S. 70° E.

No. 59: Two miles farther south these same coal beds appear in the following section:

Section of Mesaverde coal-bearing rocks at location No. 59.

	Ft.	in.
Sandstone, upper.		
Shale, brown, carbonaceous	3	
Coal	5	5
Shale, brown, carbonaceous	2	6
Sandstone	3	
Coal	4	2
Shale, brown, carbonaceous	15	
Coal	2+	
	35+	1

No. 60: In the Great Hogback, about 6 miles east of north of Ford Peak, where the upper strata of the Mesaverde formation begin to flatten and their strike changes to southeast, the following section of coal-bearing rocks is exposed beneath the upper sandstone:

Section of Mesaverde coal-bearing rocks exposed at location No. 60.

	Ft.	in.
Sandstone, massive, brown	20	
Shale, brown, carbonaceous	10	
Coal	1	9
Shale, brown, carbonaceous	2	
Sandstone	4	
Coal	3	6
Shale, brown, carbonaceous	9	
Coal	3	
Shale, brown, carbonaceous	7	
Coal	1	8
Shale, brown, carbonaceous	10	
Covered	10	
Sandstone	20	
Shale, hard, brown, containing fossil plants	3	
Coal	7	
Shale, brown, carbonaceous.		
	111	11

The beds here dip at an angle of 10° N. 75° E.

No. 61: In Captain Tom's Wash, about 1 mile above Crozier, 30 inches of coal is exposed a short distance above the lower sandstone which caps the Two Gray Hills in this vicinity. Coal beds, most of which are either thin or full of partings, were also observed in the Mesaverde strata in the wash both above and below this exposure. The Mesaverde rocks at Crozier dip toward the east at an angle of 5°.

No. 62: Four miles southeast of Sulphur Spring the upper strata of the Mesaverde formation lie practically horizontal and the following coal-bearing section is exposed below the upper sandstone:

Section of upper Mesaverde coal-bearing rocks at location No. 62.

	Ft.	in.
Shale, brown, carbonaceous.		
Coal	4	2
Sandstone and shale	50	
Shale, dark	3	
Coal	1	
Shale, brown	5	
Coal	1	10
Shale, brown, carbonaceous	6	
Sandstone, thin, shaly	12	
Coal	5	4
Shale, brown, carbonaceous	1+	
Sandstone and shale	30	
Coal	3	4
Coal, bony		1
Shale, brown, carbonaceous.		
	122	9

No. 63: About 3½ miles north of east of Crozier, near the Fruitland-Gallup wagon road, a coal bed belonging in the upper part of the Mesaverde formation has a thickness of 3 feet 7 inches. The strata here are practically flat lying. The coal appears to be good subbituminous. To the north, toward location No. 62, and to the south for about the same distance, this coal bed and others near it show a similar thickness and quality.

No. 64: About 2½ miles east of Rio Chaco and 4 miles north of the Crozier–Tiz Natzin wagon road the following coal section is exposed just above the flat-lying basal Laramie sandstone:

Section of Laramie coal bed at location No. 64.

	Ft.	in.
Clay shale.		
Coal	1	6
Shale, black		5
Coal	3	6
Shale		4
Coal	1	2
Shale, brown, carbonaceous.		
	6	11

Between this location and Coal Creek the Laramie formation is in many places hidden by the unconformably overlying Puerco marl, and in others by blown sand to such an extent that none of the coal beds of the formation were observed.

Just east of the northward bend of Rio Chaco the rocks dip north of west at an angle of about 3°, forming the eastern limb of a shallow syncline the axis of which extends southward toward the center of Zuni Basin and is probably coincident with the axis of that fold.

No. 65: In the canyon walls about 2 miles above the bend in Rio Chaco a 3-foot coal bed is exposed just below the upper sandstone of the Mesaverde formation. The strata here dip at an angle of 3° N. 60° W. Much of the coal formerly outcropping in the canyon walls in this vicinity has been burned.

No. 66: In the south wall of Chaco Canyon 3 miles below the mouth of Coal Creek the coal bed shown in the following section underlies the upper sandstone of the Mesaverde formation:

Section of Mesaverde coal bed in Chaco Canyon, at location No. 66.

	Ft.	in.
Shale, brown.		
Coal	1	
Shale	1	
Coal	7	
Coal, bony		6
	9	6

The coal appears to be a good grade of subbituminous, and is hard and blocky. The strata dip at an angle of 3° N. 20° W.

No. 67: On Coal Creek a bed of subbituminous coal near the top of the upper Mesaverde sandstone and above the horizon of any workable coal hitherto described in this formation was opened in 1901 for use at Tiz Natzin, an Indian trading post near by. A slope, subsequently abandoned, was driven for a distance of 25 feet on the coal bed, which dips N. 35° W. at an angle of 4°. The following is a section of the rocks exposed:

Section of upper Mesaverde coal-bearing rocks near Tiz Natzin, on Coal Creek, at location No. 67.

	Ft.	in.
Sandstone, limy, and containing fossil shells	2	
Sandstone, friable	30	
Coal	1	8
Coal, bony		5
Coal	3	2
Fire clay.		
	37	3

The analysis of a sample from the lower bench of this coal indicates a good grade of subbituminous coal. The coal makes a quick, hot fire and leaves a light, white ash.

No. 68: In Chaco Canyon, between the mouth of Coal Creek and Shawver's store, nearly all the coal beds exposed have been burned at their outcrops, but about midway between these localities a bed partially exposed shows a thickness of 4 feet. It lies 40 feet below the bed noted at location No. 67 and at about the horizon of the coal bed described at location No. 66.

Northeast of Shawver's store Laramie coal beds appear at a number of places between Rio Chaco and Coal Creek. Only the lower beds of the formation, including the basal sandstone, are exposed, the upper beds being concealed by overlapping Tertiary strata.

No. 69: This locality is about 3 miles north of the wagon road leading northeastward from Shawver's store. The following section of a coal bed a short distance above the basal Laramie sandstone is exposed in strata dipping N. 30° W. at an angle less than 1°:

Section of Laramie coal bed at location No. 69, 5 miles northeast of Shawver's store.

	Ft.	In.
Sandstone.		
Clay shale	2	
Coal, clear and blocky	3	4
Clay shale.		

No. 70: Two miles north of locality No. 69 and stratigraphically above the coal bed just described, the following coal section was measured:

Section of Laramie coal bed at location No. 70.

	Ft.	In.
Shale, brown, carbonaceous.		
Coal		10
Shale		5
Coal	1	5
Coal, bony, variable		¼
Coal	1	10
Shale, brown, carbonaceous.		
	4	6¼

No. 71: One mile farther north and not more than 50 feet stratigraphically above the exposure at location No. 70, the following coal section is exposed on a branch of Coal Creek:

Section of Laramie coal bed at location No. 71.

	Ft.	In.
Coal, bony, variable.		
Coal, containing fossil resin [a]	3	4
Shale, brown, carbonaceous.		

This coal is evidently of good quality. It is hard and blocky, and its high percentage of wheelerite causes it to ignite readily. The strata are nearly flat lying, and the bed, if persistent, may be mined under a considerable area.

No. 72: Two miles east of location No. 69 and near the same horizon a thick bed of Laramie coal is exposed. The strata are practically flat lying, and the coal is overlain directly by the unconformable Puerco marl. A section of the coal bed is as follows:

Section of Laramie coal bed 1½ miles north of wagon road, at location No. 72.

	Ft.	In.
Sand, unconsolidated.		
Coal		7
Shale, black, carbonaceous	1	3
Coal	1	8
Coal, bony		½
Coal	2	4
Shale		4
Coal	4	
Shale, black, carbonaceous.		
	10	2½

[a] Wheelerite, present in many of the coal beds in this field. For a description, see U. S. Geog. Surveys W. 100th Mer., vol. 3, 1875, pp. 630-631.

The lower bench in the above section is apparently of excellent quality and has the physical characteristics of cannel coal. The same bed is exposed in similar section half a mile farther east.

No. 73: In the north wall of Chaco Canyon, just below the mouth of Meyers Creek, a bed of good, shiny, black, subbituminous coal occurs below the upper sandstone of the Mesaverde formation. The bed is more than 8 feet thick, including a 3-inch bony streak. The strata dip about N. 20° W. at an angle of less than 2°. The coal bed is included in the following section:

Section of upper Mesaverde coal-bearing beds in Chaco Canyon, at location No. 73.

	Ft.	in.
Sandstone, massive	18	
Shale, dark	1	
Coal	1	
Shale, dark	4	
Sandstone, massive	5	
Coal	1	10
Coal, bony, variable		3
Coal	6	1
Shale, brown, carbonaeceous.		
	37	2

Between this point and Putnam the coal bed is exposed at several places.

No. 74: The same coal bed is mined at the Pueblo Bonita mine, in the south wall of Chaco Canyon, for use at Putnam post-office and an Indian trading post which is located at the famous Aztec ruins, Pueblo Bonita, 1 mile above. This mine was opened by the Wetherills in 1905, by a 30-foot drift to the rise of the coal bed, a section of which is as follows:

Section of coal bed in Pueblo Bonita mine in Chaco Canyon, 1 mile below Putnam, at location No. 74.

	Ft.	in.
Sandstone, upper.		
Coal, bony	1	6
Coal	3	8
Coal, bony, and sandstone, variable		4
Coal	2	4
	7	10

The analysis of a sample of coal from this mine indicates a good grade of subbituminous coal, rather high in ash. The coal bed is workable under an extensive area, has an excellent roof and floor, and both benches can be mined, as the parting is easily separable from the coal. The strata dip at an angle of about 2° N. 20° W.

No. 75: Several beds of Laramie coal are exposed in the north branch of Meyers Creek 1½ to 2 miles above the crossing of the Putnam–Ojo Alamo wagon road. The lowest bed overlies the massive

basal sandstone. The following is a section of the rocks exposed in the bed of the arroyo:

Section of Laramie coal-bearing rocks in north branch of Meyers Creek, at location No. 75.

	Ft.	in.
Coal	3+	
Shale, brown, carbonaceous	8	
Coal	1	8
Shale, brown, carbonaceous		4
Coal	2	
Coal, bony	1±	
Sandstone and shale	50	
Sandstone	2	
Coal	3	4
Shale	1±	
Sandstone and shale	15	
Coal	2	8
Parting, variable		½±
Coal	1	4
Shale, brown, carbonaceous	1	
Sandstone and shale	30	
Shale, brown, carbonaceous	1	
Coal	2	9
Shale, brown, carbonaceous.		
	126	1½±

The beds dip N. 20° W. at a low angle and are unconformably overlapped by the Puerco marl, so that they are well exposed only in the stream channels. Apparently these coals can be mined under a large area.

No. 76: In each of the three branches of Escavada Wash, northeast of Putnam, the Laramie coal beds have been burned at the outcrop and the overlying and underlying sandstone baked a brick-red color over a considerable area, so that only one measurable exposure of coal was found. The following coal section is exposed in the south branch of the wash 8 miles above the Putnam–Ojo Alamo wagon road crossing and 3 miles above its juncture with the middle fork:

Section of Laramie coal-bearing rocks in Escavada Wash, at location No. 76.

	Ft.	in.
Sandstone, light gray	5	
Shale, drab	3	
Coal	1	7
Shale, drab	2	3
Coal	4	5
Shale, brown, carbonaceous	2	

The strata dip more to the north than on Meyers Creek, but at about the same angle.

No. 77: Above Putnam the Mesaverde coal beds thin rapidly and partings come in; at a distance of 2 or 3 miles up the canyon no single bench of coal was observed to have a thickness exceeding 37 inches.

An exposure, apparently typical of the upper Mesaverde coal beds east of Putnam, occurs in strata with a low northward dip outcropping in the southward-facing mesa cliff 7 miles south of Pueblo Alto, near the wagon road between Pueblo Alto and the Seven Lakes trading post. The section is as follows:

Section of coal bed near the Pueblo Alto–Seven Lakes wagon road, at location No. 77.

	Ft.	in.
Sandstone, massive	50	
Shale, drab	5	
Coal		6
Shale, dark, carbonaceous	4	
Shale, dark	4	
Coal and bony coal	1	10
Coal	1	11½
Coal, bony		3
	67	6½

No. 78: At a point about 1½ miles farther west the following section of Mesaverde coal is exposed in the same escarpment:

Section of Mesaverde coal bed at location No. 78.

	Ft.	in.
Shale, dark	3	
Coal, bony	1	
Coal	3	1
Shale, brown, carbonaceous	3	1
	10	2

This is the thickest coal bed observed in the upper Mesaverde in the area east of Putnam. The coal is apparently at the horizon of that in the Pueblo Bonita mine and is similar in appearance and quality.

No. 79: About 2½ miles north of Mariana's store, which is situated near the Pueblo Alto ruins, the Laramie coal beds are exposed where the unconformably overlapping Puerco marl has been worn away by stream erosion. One of these beds, occurring a short distance above the basal sandstone of the Laramie, shows over 7 feet of clear coal. Another, a short distance higher, is over 5 feet thick, but the exposures are so poor that nothing definite could be learned of the quality of the coal.

Between location No. 79 and Raton Spring no exposures of Laramie coal beds were observed, on account of a covering of either blown sand or overlapping Puerco marl.

No. 80: At a point about 4 miles southeast of Raton Spring an exposure of Laramie coal shows the following section:

Section of Laramie coal at location No. 80.

	Ft.	in.
Shale, drab, carbonaceous	15	
Coal, with thin shale partings	1	5
Sandstone		1
Coal	3	
Sandstone		½
Coal	2	
Shale, brown, carbonaceous.		
Total coal bed	6	6½

The strata dip northward at an angle of 2°. North and east of Raton Spring Laramie coals were observed, but not examined in detail. They are thick and of good quality.

The Indian trader at Seven Lakes and the postmaster at Cabezon reported to the writer that very thick beds of coal, generally clear of partings and of good quality, occur well toward the head of Arroyo de los Torreones. These beds, though not examined, are undoubtedly in the Laramie formation, as they are in the strike of the beds that outcrop at Raton Spring. Simpson[a] in his "Journal" mentions the occurrence of coal in the head of this arroyo.

Between Chaco Canyon on the north and the latitude of Seven Lakes on the south the rocks are intermediate in the Mesaverde formation and are barren of coal.

No. 81: About 5 miles southwest of Seven Lakes coal beds belonging to the lower Mesaverde outcrop in a tributary of Vacinte Wash. A section including these beds is as follows:

Section of lower Mesaverde coal-bearing rocks at location No. 81.

	Ft.	in.
Shale, drab	5	
Shale, brown, carbonaceous	1	
Coal, containing fossil resin	2	
Shale, drab	30	
Coal	2	11
Shale	1	
Coal	1	
Shale, drab, fissile	8	
Sandstone and shale, red (burned coal bed).		
	50	11

The strata dip to the north at the rate of 100 feet to the mile.

No. 82: Two coal beds in the lower Mesaverde are exposed 5 miles southeast of Togay Springs, where the following section was measured:

[a] Simpson, J. H., Journal of a military reconnaissance from Santa Fe, N. Mex., to the Navajo country, 31st Cong., 1st sess., Senate Ex. Doc. No. 64, 1850, p. 30.

Section of Mesaverde coal-bearing rocks 5 miles southeast of Togay Springs.

	Ft.	In.
Shale, drab.		
Coal	2	5
Shale, carbonaceous	2	
Shale and sandstone	12	
Sandstone	3	
Coal, bony		5
Coal		1
Shale, carbonaceous	3	
Coal	2	5
	25	4

The rocks dip northward at the rate of 200± feet to the mile.

GALLUP DISTRICT.

The Gallup district includes that part of the field which lies between the latitudes of Fort Defiance, Ariz., and Manuelito, N. Mex. The present paper includes a description of only the part of the district lying west of the Continental Divide, which passes in a northeast-southwest direction along a line from the head of Rio Chaco through Hosta Butte.[a]

The topographic features are dependent primarily on structure and secondarily on stream erosion. In the interior of the coal fields the rocks are for the most part flat lying, but in places are sharply folded. The region has been deeply dissected, so as to leave wide valleys, isolated flat-topped table-lands, and here and there low, sharp-crested ridges.

The borders of the coal areas are either prominent escarpments from which the strata dip gently toward the interior or serrated ridges in which they are steeply upturned. Thus a southward-facing escarpment in which the strata dip toward the north at an angle of 2° to 3° forms the border of the field from Hosta Butte westward to the north extremity of the Nutria monocline, where the rocks change in strike from west to south, forming a hogback in which they dip westward at a steep angle. On the west the coal field is limited by the Defiance monocline. In the vicinity of Fort Defiance the rocks in this fold dip steeply to the east, but the dip flattens rapidly toward the south until at the point where the fold is crossed by the Atchison, Topeka and Santa Fe Railway, near Manuelito, it is less than 5°. The strata affected by this fold do not include to any considerable extent the coal-bearing rocks above the Dakota. The Gallup structure section (Pl. XXIII, p. 382) illustrates the nature of the local folding in the vicinity of that town.

[a] For a description of the remainder of this district, see Schrader, F. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 251-252.

Gallup is the only town of consequence in the district, but Clarkville, Weaver, and Gibson are good-sized coal-mining camps.

The coals of the Gallup district represent three formations—the Dakota, Mancos, and Mesaverde. Those of the Mesaverde are the most valuable and the only ones at present mined. The Dakota coal was examined east of Gallup in the southward-facing escarpment north of the railroad, but was found to be thin and full of partings and consequently not of present commercial value. The position of this coal is not shown on the map.

The Mancos coal occurs in a bed of thin shaly sandstone 50 feet thick at the top of the formation. These beds are present in the Nutria monocline east of Gallup and along the western border of the coal field, but the coal is known to be of commercial value only east of Mariana Lake.

The Mesaverde coal is mined extensively in this district. Beds at both the upper and lower coal horizons are present, separated by 500 feet of barren strata. The beds at both horizons carry a good-grade subbituminous coal and range in thickness up to 8½ feet. Along the southward-facing escarpment that limits the field north of the railroad and east of the Nutria monocline the Mesaverde coal beds occur at the lower horizon. These have not been mined or even prospected, but in the natural exposures examined they appear to be of the same quality as in other parts of the district where they are mined.

No. 83: A typical section of the Mancos coal is exposed in the escarpment south of the entrance to Devils Pass, about 12 miles east of north of Thoreau. The coal compares well in quality with the sample collected in 1905 from the same bed in the Tiejen prospect, 10 miles east of north from Baca. The analysis shows a good subbituminous coal. It contains considerable fossil resin, which causes it to ignite readily. The strata at location No. 83 dip east of north at an angle of 7°. The section of the coal is as follows:

Section of coal bed in Devils Pass at location No. 83.

	Ft.	In.
Shale, drab.		
Coal	2	6
Shale		3
Coal		10
Shale, brown, carbonaceous.		
	3	7

No. 84: About 2 miles north of the locality just described the following section of the lower Mesaverde is exposed in an escarpment on the east side of the pass:

Section of Mesaverde coal beds in Devils Pass 4 miles east of Hosta Butte, at location No. 84.

	Ft.	in
Sandstone, massive.		
Shale	10	
Coal	3	6
Shale and sandstone	25	
Coal	3	6
Sandstone and shale	5	
Coal	3	6
Shale	8	
	58	6

No. 85: North of Mariana Lake, at Dalton's store, on the Guam–Seven Lakes road, a prospect has been opened on one of the lower Mesaverde coal beds. The bed is 3½ feet thick and lies between shale. The dip of the strata is about 3° NNE. The coal is reported to burn well without forming clinkers and to leave a small amount of ash.

No. 86: About 1 mile south of the Navajo Indian Reservation, on the Gallup–Seven Lakes road, 5 miles northwest of Little Togay Spring, the following section of a part of the lower Mesaverde is exposed:

Section of lower Mesaverde rocks at location No. 86.

	Ft.	in.
Sandstone, massive.		
Shale, brown, carbonaceous	1	6
Sandstone and shale	8	
Coal	3	6
Sandstone and shale	15	
Coal	2	6
Shale	8	
Sandstone, massive	15	
Sandstone and shale	17	
Coal, bony	1	
Shale, drab	4	
Coal	2	
Shale	20	
Coal	5	
	102	6

No. 87: North of the divide, about a mile west of the Gallup–Seven Lakes wagon road and about 3 miles northwest of the locality just described, the following section in the Mesaverde formation is exposed. It may represent in part the section of location No. 86.

Section including upper Mesaverde coal beds at location No. 87.

	Ft.	in.
Sandstone	8	
Shale, brown, carbonaceous	4	
Coal	2	6
Shale, brown, carbonaceous	1	
Shale	12	
Coal	3	6
Shale, brown, carbonaceous	3	
Coal	1	6
Shale	4	
Coal	1	2
Shale	5	
Coal	1	
	46	8

No. 88: The coal beds of the Weaver mine, 3 miles north of Gallup, occur in the upper Mesaverde, which is here about 100 feet thick. The section shown below, based in part on drill records obtained from the American Fuel Company, shows six workable coal beds.

Section of upper Mesaverde coal-bearing rocks at the Weaver mine, 3 miles north of Gallup.

	Ft.	in.
Coal	1	
Fire clay	2	
Coal, dirty, No. 1	3	6
Sandstone and shale	14	
Coal		6
Fire clay	7	
Coal, No. 2	4	6
Sandstone and shale	24	
Coal, No. 3	4	
Fire clay	2	
Sandstone	5	
Draw slate	1	6
Coal, No. 3½	6	3
Fire clay	2	6
Sandstone, shale, and thin coal seams	20	
Coal, with many shale partings, No. 4	3	
Sandstone	20	
Coal, No. 5	6	6
	127	3

All these beds have been worked at the Weaver mine, which is the largest producer in the district. At present only one bed—No. 3½—is being mined extensively, although some coal is being taken from bed No. 3. The roof of bed No. 3½ is firm shale and the floor fire clay. A slope has been driven for more than 4,000 feet west of north, on a dip ranging from 4° to 15°. Cross entries have been driven for 800 feet on either side of the main entry and diamond-drill prospecting has been carried a mile ahead of the workings. A number of small

rolls and faults have been encountered in the mine. Analyses show this to be a high-grade subbituminous coal.

No. 89: The Gallup mine is situated at Gibson, near the Weaver mine. Coal beds Nos. 3, 3½, and 5 were worked until early in 1904, when fire closed the mine and it has not yet been reopened. It was operated by a slope driven 5,000 feet on the dip of the coal bed.

No. 90: The Heaton mine, opened by the American Fuel Company in June, 1904, is working bed No. 3½. The mine is operated by a drift, which has been driven for more than 2,500 feet N. 25° W. on the dip of the coal, which ranges from 2° to 15°. The average thickness of the bed is about 3 feet 10 inches, including unimportant thin partings that are locally present. The roof of the coal bed is shale, the floor sandstone.

No. 92: The Otero mine, not now in operation, is located about 3 miles east and 1 mile north of Gallup. The coal beds worked at this mine occur in the lower Mesaverde formation. The section as exposed in the mine is as follows:

Section of lower Mesaverde coal beds in Otero mine, at location No. 92, near Gallup.

	Ft.	In.
Coal, Crown Point bed	3	5
Shale		8
Coal	1	5
Sandstone	11	
Coal, Thatcher bed	4	
Shale and sandstone	6	
Shale	9	
Coal, Black Diamond bed	1	6
Sandstone and shale	88	
Coal	1	2
Shale		9
Coal, Otero bed	3	2
Shale (?).		

Samples were collected from the Crown Point, Thatcher, and Otero beds. The coals are of a good subbituminous grade.

No. 94: The Union mine, situated about 2 miles south of Gallup, is working the Crown Point bed, which has an average thickness of about 6 feet, including a parting 2 feet from the top. The roof is shale and the floor fire clay. The mine is operated by a slope driven for more than 1,000 feet on the dip of the bed, S. 70° W. at an angle of 15°.

No. 95: The Rocky Cliff shaft, 2½ miles from Gallup, is situated a short distance south of Gibson. In it one of the beds of the lower Mesaverde is worked. The shaft is 250 feet deep. The average thickness of the bed is 5 feet.

No. 98: The Clark mine is situated at Clarkville, a mining camp about 4 miles west of Gallup. Diamond-drill borings have shown

the presence here of 5 coal beds of the upper Mesaverde, which in descending order have the following thicknesses:

Thicknesses of coal beds at Clarkville.

	Feet.
First bed	2½
Second bed	3½
Third bed	4½-8½
Fourth bed	5½
Fifth bed	4

Only the third bed is mined at present. The strata vary in dip throughout the mine, ranging from a very low angle to 4½° N. 70° E. Horsebacks and rolls are numerous in the mine. The partings in the bed mined, a section of which is given below, are nearly everywhere present, but vary greatly in thickness and are easily separable from the coal.

Section of upper Mesaverde coal bed in Clark mine, Clarkville, location No. 98.

	Ft.	in.
Shale, carbonaceous, brown and white streaked	1±	
Coal, not mined	3±	
Shale, brownish, sandy	4±	
Coal	2	
Coal, bony	1±	
Coal	2	
Shale, bituminous		3±
Coal	3	3
Fire-clay floor.		

Other mines in the district in which work is at present suspended on account of a decrease in the coal demand are the Rocky Cliff, Thatcher, Catalpa, and Casna.

Near Defiance switch three coal beds of the lower Mesaverde are exposed. The coal-bearing strata have a thickness of about 150 feet, and they dip north of east on the east limb of the local anticline, which trends north and south near Defiance switch and plunges at a steep angle in each direction away from the railroad.

No. 99: About 1¼ miles east of north from Defiance switch, D. M. Smith, a trader, opened a mine and shipped a few cars of coal in 1886. The mine was shortly afterwards abandoned. The coal worked is the lowest bed in the lower Mesaverde. It occurs in strata dipping N. 30° E. at an angle of 4°. The coal appears to be of good quality. A section including it is as follows:

Section of lower Mesaverde coal-bearing beds at abandoned Smith mine near Defiance switch, location No. 99

	Ft.	in.
Sandstone, massive	70	
Shale, carbonaceous	10	
Coal	2	9
Shale, carbonaceous	12	
Coal	4	
Shale, carbonaceous	1	
	99	9

No. 100: About 2 miles west of north from Defiance switch the following coal section is exposed in the lower Mesaverde, about 100 feet stratigraphically above the coal section just given:

Section of lower Mesaverde coal bed at location No. 100.

	Ft.	in.
Sandstone, thin bedded	2	
Shale, carbonaceous	1	
Coal	3	4
Shale, carbonaceous	15	
Coal	2	4
Shale, carbonaceous	5	
Coal	1	6
Shale, dark	3	
	33	2

No. 101: At an abandoned prospect about one-half mile northwest of location No. 100 a 4-foot bed of good subbituminous coal occurs about 60 feet stratigraphically above the section just given. The strata dip N. 70° E. at an angle of 4°.

The coal beds of the Mancos shale are generally thin and probably not of workable thickness anywhere along the western border of the coal field. They occur in a series of thin sandstone and shale beds at the top of the Mancos formation.

No. 102: About 2½ miles northwest of Manuelito, in rocks having a low dip to the west, Mancos coal is exposed as shown in the following section:

Section of Mancos coal 2½ miles north of Manuelito, at location No. 102.

	Ft.	in.
Fire clay		8
Coal, bony	2	
Coal		6
Shale		3
Coal		8
Sandstone, argillaceous	3	
Shale, dark		6
Coal, bony toward top	2	8
Shale, carbonaceous	20	
	30	3

No. 103: Six miles northwest of Defiance switch two coals of the lower Mesaverde are exposed. A section including these beds is as follows:

Section of lower Mesaverde coal-bearing rocks at location No. 103.

	Ft.	In.
Sandstone, massive	20	
Shale, drab	12	
Coal	3	5
Coal, bony, variable		1
Coal	2	9
Shale, carbonaceous	2	
Shale and sandstone	8	
Shale, drab		4
Coal	1	3
Coal, bony		6
Coal	1	3
Shale, carbonaceous	1	
	52	7

No. 104: Two miles west of north of location No. 103 the following section of the lower Mesaverde is exposed:

Section of lower Mesaverde coal-bearing rocks at location No. 104.

	Ft.	In.
Shale	25	
Coal, containing fossil resin	1	10
Shale, drab	6	
Coal	1	
Shale, drab	2	
Coal	6	
Sandstone	2	
Shale and sandstone	30	
Coal	1	
Shale, brown	4	
Coal		6
Shale, drab	20	
Coal	4	4
Coal, bony	1	
Coal	1	6
Shale	4	
Coal	1	6
Shale	3	
	114	8

The 6-foot bed near the top of this section is equivalent to the upper bed exposed at location No. 103. A large area in this vicinity is underlain by these coal beds and promises to be a good field for future development.

No. 105: At the St. Michaels mine, near the St. Michaels–Gallup wagon road 5 miles south of east of St. Michaels, Ariz., a coal bed in the lower Mesaverde was opened in 1904 to supply fuel for the mis-

sion school at St. Michaels. A tunnel was driven 35° E. for about 250 feet. The coal compares well with the best coals of the district. It is 53 inches thick and has a good sandstone roof and bony-coal floor.

No. 106: The Agency mine, situated 7 miles southeast of Fort Defiance, Ariz., has during the last ten or twelve years supplied coal for the Navajo Agency and school at Fort Defiance. About 600 tons are mined annually. The bed ranges from 5 to 6 feet in thickness. The roof is sandstone and the floor shale. The strata have a low easterly dip. Apparently the character of the coal is similar to that mined at the St. Michaels and it is probably the same bed. Unquestionably the coal beds are within the lower Mesaverde.

In the vicinity of the St. Michaels and Agency mines several other coal beds contained in the lower Mesaverde outcrop, four or five of them being of workable thickness and good quality. About midway between Fort Defiance and Tohatchi, near the wagon road at the foot of the steep hill, several of these coal beds outcrop, ranging up to 3 feet in thickness. The strata here dip 70° E. at an angle of 10°.

No. 107: A 3-foot bed of coal occurring in the lower Mesaverde outcrops north of the wagon road just mentioned 6 miles southwest of Tohatchi. A short distance north of this locality the Mesaverde formation dips at an angle of 10° and disappears beneath the unconformably overlying Tertiary clay shale of the Choiskai Mountains.

ZUNI DISTRICT.

The Zuni district includes the extreme southern extension of the coal field south of the Gallup district. It occupies a narrow north-south synclinal basin and extends from the latitude of Manuelito on the north to Salt Lake on the south. East and west the coal field of this district is limited by southward continuations of the Nutria and Defiance monoclines, respectively.

Along the western base of the Zuni Mountains the rocks in the Nutria monocline dip steeply away from the mountains. The outcropping edges of the hard rocks form sharp-crested ridges, between which are narrow valleys that have been cut in the softer sandstones and yielding shales. South of Ramah the fold is less pronounced and the coal-bearing rocks dip gently toward the interior of the basin. A short distance south of Manuelito the rocks in the Defiance monocline become less steeply tilted until in the latitude of Zuni village the coal-bearing rocks dip gently to the east toward the center of the district.

North of Zuni River the interior of the coal field is a wide piñon-covered table-land. Its surface is broken here and there by projecting, isolated buttes and by canyons. The Zuni plateau, which

includes the coal field south of Zuni River, is bounded on the east by an extensive lava flow, a tongue of which crosses the coal field south of Tarche in a wide belt and extends as far as the Arizona line. This lava flow forms a prominent table-land throughout its extent and, in connection with a fault of considerable magnitude which was observed 1 mile south of Ojo Caliente trending south of east, isolates the coal field in the southern part of the plateau. This part of the district will hereafter be designated the Salt Lake region. The relations of the lava flow, the coal rocks, and the fault are shown on the map (Pl. XXII) and in the structure sections (Pl. XXIII).

The workable coal beds of this district occur presumably in the Mancos formation. Fossils were collected north of Salt Lake in limy sandstone 35 feet below the lowest coal bed of the district and were determined by Stanton to be of Colorado age. As has already been stated, however, it is possible that the contact between the Mancos and Mesaverde formations lies between this fossil horizon and the coal beds, and if this is true the coals would be correlated with the lower Mesaverde. No bed of clear coal was observed of greater thickness than 4 feet. Since in the Salt Lake region the coal-bearing rocks are overlain in large areas by lava and unconformable Tertiary(?) strata, a determination of the presence of workable coal beds can be accomplished only by prospecting.

No. 108: In the monocline, about 4 miles east of south from Nutria, the following coal section is exposed in beds of the Mancos formation, which dip S. 40° W. at an angle of 16°.

Section of Mancos coal bed at location No. 108.

	Ft.	in.
Sandstone, coarse-grained	6	
Shale, dark, carbonaceous	1	
Coal	3	9
Shale, carbonaceous	10	
Shale and sandstone	12	
Coal		10
	33	7

The same bed, 40 inches thick, was observed to outcrop at a point about 1 mile south of this locality.

Nos. 109 and 110: Near the Nutria-Zuni road, midway between these towns, two mines were opened recently on coal beds of the Mancos formation. These mines supply fuel for the Zuni school and for use in the construction of a large dam at Blackrock. At the Harper mine (No. 109) the lowest of three beds outcropping in the vicinity has been opened by a 300-foot slope on the dip of the bed, which is N. 60° E. at an angle of 3°. The coal, as shown in the subjoined section, is full of partings. It is of inferior quality, though the 11-inch bench is an excellent blacksmith's coal.

Section of Mancos coal bed in Harper mine, at location No. 108.

	Ft.	in.
Shale roof.		
Coal, bony		4
Coal		5
Coal, bony		5
Coal	1	2
Coal, bony		5
Coal		11
Coal, bony		5
Coal		9
Fire clay.		
	4	10

The School mine (No. 110), situated about one-half mile northwest of the Harper mine, is in a bed of coal about 50 feet stratigraphically above the section just given. At the time visited this mine had just been opened by a short entry. An analysis of a sample taken at the working face shows the coal to be a good-grade subbituminous, although rather high in ash. The bed is 40 inches thick and lies between a shale roof and a fire-clay floor. About 7 feet above this coal occurs another bed which shows 34 inches of good, clear coal. The roof and floor are massive sandstone, each separated from the coal by about 2 inches of clay shale.

No. 111: Near the top of the mesa, about 10 miles east of Zuni village, the following section of a Mancos coal bed was measured in strata dipping eastward at a low angle:

Section of Mancos coal at location No. 111.

	Ft.	in.
Shale, gray, sandy	2	
Coal, bony	1	
Coal, bony at top	2	6
Coal, bony		2
Coal	2	6
Shale, drab.		
	8	2

No. 112: About 6 miles northeast of the Miller ranch, underlying a massive pinkish sandstone which is a prominent horizon marker in this vicinity, a Mancos coal bed 3 feet 2 inches thick, with shale roof and floor, is exposed in strata dipping to the north at a low angle. The same coal bed was observed at a point 1½ miles farther west and about 1 mile north of the Miller ranch.

In the head of Carrizo Valley, in the Salt Lake region, coal beds are exposed in the Mancos formation at numerous places. The maximum observed thickness of these beds is about 4 feet of clear coal.

No. 113: West of the Salt Lake–Tarche wagon road about 6 miles north of Papalota, where a Mexican store is located, the subjoined section of the Mancos coal beds is exposed in the mesa cliff. The

strata dip northward at a low angle beneath unconformably overlying Tertiary sediments.

Section of Mancos coal beds at location No. 113.

	Ft.	in.
Shale, drab	6	
Coal	2	8
Shale, black	1	
Shale, drab	20	
Coal, bony	1	
Shale	2	
Coal, with variable sandstone parting	2	
Shale	2	
Coal	1	
Coal, bony		1
Shale, sandy	14	
	51	9

No. 114: One mile east of the Salt Lake–Tarche wagon road and 6 miles east of north of Papalota, the following coal section occurs in Mancos strata, which dip S. 70° W. at an angle of 2°:

Section of Mancos coal bed at location No. 114.

	Ft.	in.
Shale, drab	3	
Shale, carbonaceous	1	
Coal	2	8
Shale, carbonaceous	1	
Coal	2	2
Shale, dark	1	2
	11	

At a point 1 mile farther south the lower bench of this coal bed is 26 inches thick and the parting measures nearly 1 foot, the upper bench remaining the same thickness.

No. 115: Two miles southeast of location No. 114 the following section of Mancos coal is exposed in flat-lying strata:

Section of Mancos coal bed at location No. 115.

	Ft.	in.
Shale, dark	1	
Coal	1	11
Coal, bony		10
Coal		11
Coal, bony		2
Coal	1	2
Coal, bony		5
Coal		10
Coal, bony		4
Shale, carbonaceous	5	
Total coal bed	6	7

No. 116: About 4½ miles north of east of Papalota a bed of Mancos coal outcrops in the escarpments of a wide, low mesa. The bed has

a thickness ranging from 30 to 36 inches and is free from partings The roof is sandstone and the floor carbonaceous shale. This bed can be mined under a considerable area in this vicinity.

No. 117: Eight miles north of Salt Lake, near the Provencer ranch, prospectors from Silver City, N. Mex., about ten years ago drove an entry for 30 feet in a Mancos coal bed. It is reported that $1,000 was spent by these people in prospecting the coal beds of this vicinity and that 30 coal entries were filed on but never proved up. The entry just referred to shows the following section:

Section of Mancos coal at Provencer prospect, location No. 117.

	Ft.	in.
Shale.		
Coal	2	
Coal, bony, sandy		½
Coal	1	
Coal, bony, sandy		½
Coal	1	
Shale, brown, carbonaceous.	4	1

No. 118: About 2 miles north of west of location No. 117 the Mancos coal-bearing rocks show the following section, which includes the thickest and best coal beds observed in this vicinity:

Section of Mancos coal beds at location No. 118.

	Ft.	in.
Shale.		
Coal	4	
Shale	6	
Coal	3	6
Shale.	13	6

This section occurs about 80 feet above the limy sandstone mentioned on page 380, in which fossils of Colorado age were collected.

CHARACTER OF COAL.

Throughout the Durango-Gallup field the coals have a bright luster and are clean to handle. When freshly mined they are hard but brittle and break badly with handling, thus producing a high percentage of fine coal. This fine coal or slack is in the greater part of the area waste, as the coals, except those in the Durango region, do not coke. In the Gallup district this waste amounts to nearly 20 per cent of the run-of-mine coal. In the vicinity of Durango, however, the fine coal is coked and the product used in the smelters of the region. The coke gives excellent satisfaction, but is reported not to bear shipment well, being somewhat brittle.

In the Gallup district the coals have a low specific gravity and give the best satisfaction under stationary boilers, as unburned fragments of the coal blow out of the stacks of locomotives on account of high forced draft. Throughout the field the coals are good domestic and steam-producing coals.

During the present work samples representative of the various coal beds were collected from mines and prospects in the coal field. Each sample was taken with great care and is thought to be representative of the bed in the opening in which it was taken. With two or three exceptions, all the samples were taken by making a cut across a fresh working face, including all the coal mined and excluding such partings as in practice are rejected. This material was pulverized and quartered in the mine and sent in sealed cans to the United States Geological Survey fuel-testing plant, where the analyses given in the following tables were made by F. M. Stanton.

Proximate analyses of coals from Durango-Gallup field, Colorado-New Mexico.

	Location.	Formation.	Name of coal bed.	Thickness of coal.		Sampler.
				Ft.	*in.*	
1	8 miles north of Mancos, Colo	Dakota		2	9	J. A. Taff. C. D. Smith.
2	Porter Colo	Mesaverde		3	7½	J. A. Taff.
3	do	do		2	2	Do.
4	Near Durango, Colo	do		5	6	J. A. Taff. C. D. Smith.
5	Porter, Colo	do		2	7½	J. A. Taff.
6	do	do	Porter No. 3	3	0	M. R. Campbell.
7	Hesperus, Colo	do		5	0	J. A. Taff.
8	Near Durango, Colo	do		6	10¾	M. K. Shaler
9	Hesperus, Colo	do		5	4	Do.
10	5 miles northeast of Pendleton, N. Mex.	Laramie	Carbonero	4	10	Do
11	Mancos, Colo	Mesaverde	Spencer	4	4	J. A. Taff.
12	do	do	do	3	0	J. A. Taff. C. D. Smith.
13	1½ miles northwest of Pendleton, N. Mex.	Laramie	Carbonero	7	0	F. C. Schrader. M. K. Shaler.
14	Mancos, Colo	Mesaverde	Spencer	3	0	J. H. Gardner.
15	1 mile west of Putnam, N. Mex	do		6	2	M. K. Shaler.
16	3 miles north of Gallup, N. Mex	do	Weaver No. 3	4	1	M. R. Campbell.
17	1½ miles east of Gallup, N. Mex	do	Otero	5	1	Do.
18	South of Cortez, Colo	do	Spencer	2	5	J. H. Gardner.
19	7 miles east of St. Michaels, Ariz	do		4	5	M. K. Shaler.
20	1½ miles northwest of Fruitland, N Mex.	Laramie	Carbonero	5	0	F. C. Schrader. M. K. Shaler.
21	Clarkville, N. Mex	Mesaverde		8	6	M. K. Shaler.
22	10 miles northeast of Blackrock, N. Mex.	Mancos		3	4	Do.
23	1½ miles east of Gallup, N. Mex	Mesaverde	Thatcher	4	0	M. R. Campbell.
24	3 miles north of Gallup, N. Mex	do	No. 3½	6	9	Do.
25	1½ miles east of Gallup, N. Mex	do	Crown Point	5	6	Do.
26	3 miles north of Gallup, N. Mex	do	No. 3½	6	9	Do.
27	30 miles west of Putnam, N. Mex	do		3	2	M. K. Shaler.
28	17 miles northeast of Thoreau, N. Mex.	Mancos		4	9	F. C. Schrader.

Proximate analyses of coals from Durango-Gallup field, Colorado-New Mexico—Cont'd.

	Laboratory No.	Analysis of sample as received.				Air-drying loss.	Analysis of air-dried sample.				Sulphur.	Fixed carbon + Volatile matter + H_2O.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.		Moisture.	Volatile matter.	Fixed carbon.	Ash.		
1	3993	1.54	31.26	53.80	13.40	0.60	0.95	31.45	54.13	13.47	1.02	1.67
2	3996	2.57	32.92	55.27	9.24	1.10	1.49	33.39	55.87	9.35	.73	1.60
3	3997	2.02	34.92	55.89	7.17	.90	1.13	35.24	56.40	7.23	.48	1.55
4	3994	2.87	35.60	54.37	7.16	1.00	1.89	35.96	54.92	7.23	2.31	1.45
5	3995	3.33	34.85	52.68	9.14	1.90	1.45	35.52	53.70	9.22	1.15	1.45
6	2092	2.73	36.05	54.48	6.74	1.30	1.44	36.52	55.20	6.83	.54	1.44
7	3950	5.71	36.16	52.78	5.35	2.70	3.10	37.16	54.24	5.50	.67	1.35
8	3552	3.64	37.79	53.35	5.22	1.60	2.07	38.40	54.22	5.31	1.38	1.34
9	3573	5.55	36.23	52.53	5.69	2.30	3.33	37.08	53.77	5.82	.66	1.33
10	3639	7.14	33.54	46.73	12.59	3.00	4.27	34.58	48.18	12.97	.57	1.25
11	3991	6.12	35.86	49.44	8.58	2.50	3.71	36.67	50.82	8.80	.64	1.25
12	3992	5.42	38.14	51.29	5.15	2.00	3.48	38.94	52.33	5.25	.80	1.23
13	2465	8.30	35.56	47.89	8.25	4.60	3.88	37.28	50.19	8.65	.69	1.22
14	4225	5.44	38.71	50.10	5.75	2.00	3.51	39.50	51.12	5.87	1.03	1.19
15	3823	17.46	32.92	41.26	8.36	9.70	8.59	36.46	45.69	9.26	2.44	1.01
16	1023, 1024	11.77	41.85	43.11	3.26	.....	.....	.....	.....	.....	.....	.....
17	1038	10.80	40.35	42.77	6.08	.....	.....	.....	.....	.....	.....	.....
18	4226	20.92	31.37	41.26	6.45	9.40	12.72	34.62	45.54	7.12	.47	.96
19	4112	14.49	37.08	44.58	3.85	5.10	9.89	39.07	46.98	4.05	.42	.96
20	2464	9.89	38.44	41.48	10.19	4.50	5.65	40.25	43.43	10.67	.67	.95
21	2434	13.95	38.43	42.12	5.50	9.30	5.12	42.37	46.45	6.06	.59	.95
22	3952	7.76	37.60	38.66	15.98	3.90	4.01	39.12	40.22	12.62	1.54	.93
23	1028	9.68	41.42	40.82	8.08	.....	.....	.....	.....	.....	.....	.....
24	1026	11.00	42.63	42.44	3.93	.....	.....	.....	.....	.....	.....	.....
25	1027	9.13	40.77	40.23	9.87	.....	.....	.....	.....	.....	.....	.....
26	1025	10.92	42.63	42.35	4.10	.....	.....	.....	.....	.....	.....	.....
27	3811	15.79	34.99	39.85	9.37	7.60	8.86	37.86	43.13	10.14	1.92	.92
28	2361	15.03	37.26	41.97	5.74	5.20	10.37	39.30	44.27	6.06	.60	.90

Ultimate analyses of selected coal samples from Durango-Gallup coal field, Colorado-New Mexico.

	Near Durango, Colo.	Hesperus, Colo.	Mancos, Colo.	7 miles east of St. Michaels, Ariz.	10 miles northeast of Blackrock, N. Mex.	3 miles northwest of Gallup, N. Mex.	14 miles east of Gallup, N. Mex.	30 miles west of Putnam, N. Mex.
Laboratory No.	3552.	3573.	4225.	4112.	3952.	1278.	1307.	3811.
Analysis of sample as received:								
Prox. Moisture	3.64	5.55	5.44	14.49	7.76	12.29	10.79	15.79
Prox. Volatile matter	37.79	36.23	38.71	37.08	37.60	34.58	33.82	34.99
Prox. Fixed carbon	53.35	52.53	50.10	44.58	38.66	46.14	36.73	39.85
Prox. Ash	5.22	5.69	5.75	3.85	15.98	6.99	18.66	9.37
Ult. Sulphur	1.36	.64	1.01	.41	1.48	.63	1.26	1.78
Ult. Hydrogen	5.39	5.46	5.80	6.02	5.67	5.82	5.22	5.93
Ult. Carbon	75.40	72.70	72.26	63.41	60.55	63.31	55.07	55.74
Ult. Nitrogen	1.48	1.37	1.47	1.23	.99	1.03	.95	1.39
Ult. Oxygen	11.15	14.14	13.71	25.08	15.33	22.22	18.84	25.79
Calorific value determined:								
Calories	7,553	7,289	7,170	6,371	6,248	6,251	5,504	5,539
British thermal units	13,595	13,120	12,906	11,468	11,246	11,252	9,907	9,970
Loss of moisture on air drying	1.60	2.30	2.00	5.10	3.90	1.60	2.90	7.60
Analysis of air-dried sample:								
Prox. Moisture	2.07	3.33	3.51	9.89	4.01	10.86	8.13	8.86
Prox. Volatile matter	38.40	37.08	39.50	39.07	39.12	35.14	34.82	37.87
Prox. Fixed carbon	54.22	53.77	51.12	46.95	40.22	46.90	37.83	43.13
Prox. Ash	5.31	5.82	5.87	4.05	16.62	7.10	19.22	10.14
Ult. Sulphur	1.38	.66	1.03	.42	1.54	.64	1.30	1.92
Ult. Hydrogen	5.29	5.32	5.69	5.75	5.45	5.73	5.05	5.50
Ult. Carbon	76.63	74.41	73.73	66.81	63.00	64.34	56.71	60.32
Ult. Nitrogen	1.50	1.40	1.50	1.28	1.03	1.05	.98	1.51
Ult. Oxygen	9.89	12.39	12.18	21.69	12.36	21.14	16.74	20.61
Calorific value determined:								
Calories	7,676	7,461	7,316	6,723	6,500	6,353	5,668	5,994
British thermal units	13,816	13,429	13,163	12,083	11,702	11,435	10,202	10,790
Carbon-hydrogen ratio	14.48	13.99	12.96	11.60	11.56	11.23	11.23	11.00

The ultimate analyses given in the second of these tables and the physical character of the coals show that they may be classified as ranging in quality from high-grade bituminous to high-grade subbituminous coals. According to the carbon-hydrogen ratio of classification proposed in 1905 by M. R. Campbell,[a] these coals fall into the following groups:

The Perrine Peak coal of the Mesaverde formation falls into group G, which includes high-grade bituminous coals of the Appalachian field from West Virginia, Pennsylvania, Kentucky, Alabama, etc. All the Mesaverde coals of the Durango-Porter region likewise fall into this group.

The coals from Hesperus and Mancos fall into group H, which includes the best bituminous coals of the eastern and western interior coal fields from Indian Territory, Kansas, Illinois, Kentucky, Iowa, Missouri, etc.

The coals from the neighborhood of St. Michaels, Ariz., and of Blackrock, N. Mex., fall into group I, which includes lower-grade bituminous coals from Iowa, Illinois, Indiana, Wyoming, Montana, etc.

The Mesaverde coals from the Chaco region and from the Gallup district fall into group J, which includes subbituminous coals and lignites from Texas, Colorado, North Dakota, and Wyoming.

According to the analyses made at the United States Geological Survey fuel-testing plant of samples of coal collected during 1906 by various members of the Survey in different coal fields of the West, given elsewhere in this volume, the high-grade bituminous coals of the Durango region are as good as the best bituminous coals in any other of these western fields. The Laramie coal of the Durango-La Plata region has a higher fuel value than any other coals of that age in the West except those of the Grand River and Book Cliffs fields of Colorado and eastern Utah.

A classification based on proximate analyses is very satisfactory for the comparison of coals of a similar grade in any one area. As will be seen by reference to the first of the two foregoing tables, in which the analyses are arranged in the order of their relative fuel values according to the ratio $\frac{\text{Fixed carbon}}{\text{Volatile matter} + \text{water}}$, the coals of the Durango-Hesperus-Laplata region are the best in the field; the Mesa Verde coals, except that of the Todd mine, are second, and the coals of the area south of San Juan River are the poorest in quality.

Ash being left out of consideration, it is thus plain that the quality of the coals in this field is in a general way not dependent on geologic age, but on the degree of metamorphism that they have suffered. Very evidently the proximity of the coals of the northern part of the

[a] Classification of coals: Trans. Am. Inst. Min. Eng., Washington meeting, May 1, 1905.

area to the great San Juan uplift had a controlling influence over this greater degree of metamorphic change.

Were it not for the high percentage of ash and water present in the coals of Laramie age, in the northern part of the field, their fuel values would be equal to those of the Mesaverde coals of that region.

DEVELOPMENT AND MARKETS.

The earliest development of the coal resources of this field, outside of small workings to supply a limited domestic demand, began with the advent of the railroads. The Denver and Rio Grande Railroad reached Durango in 1881. It was late in the eighties, however, before any great activity in coal mining began in the northern part of the field. In the vicinity of Gallup, coal mining began late in 1881 or early in 1882, at about the time the Atlantic and Pacific Railroad (Atchison, Topeka and Sante Fe) reached Gallup from the East. The Rio Grande Southern Railway was built northwestward from Durango in 1892.

The total coal production to date in that part of the Durango-Gallup field under consideration is 10,000,000 short tons, valued at the mines at approximately $15,000,000. The output since 1901 has been about 650,000 tons[a] yearly, without any considerable variation from year to year during that period. Coke has been produced in the Durango region to the value of about $30,000 yearly since the advent of the Rio Grande Southern Railway.

The greatest development has taken place in the Gallup district, where the output since 1900 has trebled that of the remainder of the field. That the development in this district is not greater is due to a single factor—lack of demand for the product. The demand for Gallup coal is kept at its present status partly on account of the substitution of oil from California and Texas for coal as fuel on the railways of the West and Southwest, and partly on account of the lack of direct railway connection with the mining region of southern Arizona and the absence of railway competition which might lessen freight rates. Aside from the Gallup district most of the development of the coal resources of this field has been in the Durango-Mancos district. The market for this part of the field is the mining camps of the San Juan region and the Denver and Rio Grande and Rio Grande Southern railways.

The development in this coal field has been entirely dependent on railway facilities. There are good markets for coal and coke which could be economically reached from any part of the field if railway connections were established and freight rates were rendered more reasonable by competition.

[a] This figure includes coal made into coke.

Throughout the field the conditions for economical mining are favorable so far as topography is concerned. Railways with light grades, to which the coal beds of the area would be easily accessible, could be constructed almost anywhere through the field. In the northern, western, and southern parts timber available for mining purposes is at hand, but the country in the vicinity of Rio Chaco is barren of forests. In the interior of the field water in quantity can undoubtedly be obtained at moderate depths by boring. This has already been proved in the Gallup district, where an ample supply of artesian water has been obtained at a depth of about 1,000 feet. In the northern part of the field the streams carry an abundant water supply throughout the year.

THE UNA DEL GATO COAL FIELD, SANDOVAL COUNTY, N. MEX.

By Marius R. Campbell.

General description.—The Una del Gato coal field is located in Sandoval County, N. Mex., about 15 miles south of Los Cerrillos and 14 miles east of a stopping place on the Santa Fe Railway known as Algodones. (See fig. 4.) It lies in a depression between the Ortiz Mountains on the east and the north end of the Sandia Range on the southwest. The coal is best developed in T. 13 N., R. 6 E., but it is known to extend to the north into T. 14 N., R. 6 E., and to the east into T. 13 N., R. 7 E. It is probably connected with the Cerrillos coal field, but the intervening country is so deeply covered with gravel that the indurated rocks are largely concealed, and hence the exact relationship is unknown.

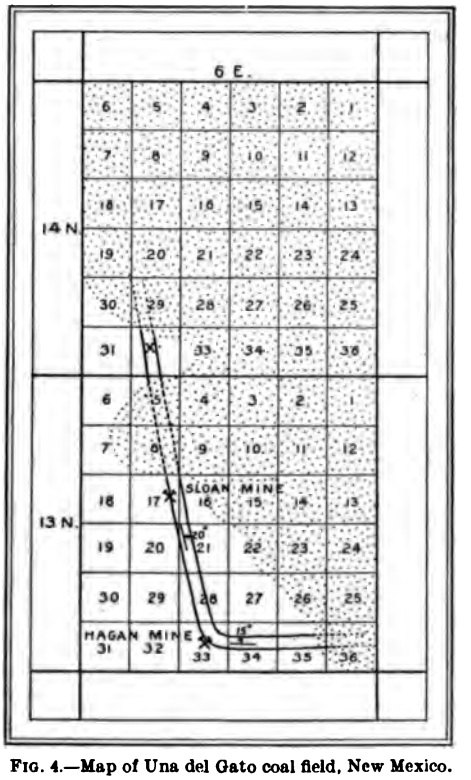

Fig. 4.—Map of Una del Gato coal field, New Mexico.

The field is not yet developed on a commercial scale, as it has no railroad connection. The most work has been done at the south end, in what is known as the Hagan field. This is mainly comprised in secs. 33 and 34, T. 13 N., R. 6 E. Another point of development is in sec. 17, in what is known as the Sloan field. The northern extremity has been extensively worked in the past and is known as the Pina Vititos field.

In the hasty visit which the writer paid to this field no opportunity was afforded for determining the age of the coal-bearing rocks, but it is highly probable that they are Laramie, corresponding to the coal-bearing beds of the Cerrillos field. In the Una del Gato field the coal beds occur in a formation composed largely of sandstone. Its character is well shown by the following section, measured by Charles R. Keyes,[a] near the Sloan mine:

Section of coal-bearing rocks at Sloan mine.

	Ft.	In.
Sandstone, massive, yellow	20	
Shale, drab	4	
Coal	2	
Shale, sandy	6	
Coal	2	
Clay		6
Coal	2	
Shale, drab	5	
Coal	1	
Sandstone, soft, yellow	5	
Coal	4	
Shale, sandy	4	
Sandstone, yellow	3	
Shale, variegated	20	
Sandstone, yellow	2	
Shale, light	10	
Coal, impure on outcrop	5	
Shale, with 6 inches of gypsum	11	
Sandstone, shaly	3	
Shale, drab	5	
Coal	1	
Shale, light	8	
Coal	1	
Sandstone, generally massive	116	
	240	6

The country between the mountain ranges has been reduced to a peneplain and then deeply covered with gravel. On account of this covering the coal beds are visible only where the gravel cap has been removed. The rocks are thus exposed throughout secs. 33 and 34, T. 13 N., R. 6 E., striking east and west and dipping about 15° N. Near the center of sec. 33 the rim of the basin turns to the north almost at right angles and the rocks are well exposed for a distance of 3 miles to the Sloan mine. Throughout this course the strike is nearly north and south and the dip about 20° E. North of the Sloan mine the mesa is not dissected for about 2 miles and consequently the rocks do not appear, but they are again well exposed in sec. 32, T. 14 N., R. 6 E., in what is known as the Pina Vititos field, where a small stream has cut across the rim of the basin, exposing all of the beds.

[a] Unpublished private report.

Hagan mine.—This is the most important mine in the field. It is located near the center of sec. 33, T. 13 N., R. 6 E., at the point where the rim of the basin turns abruptly from an east-west to a north-south course. The coal mined is known locally as the Hopewell bed. It outcrops near the base of the cliffs and the mine has been driven down on the dip (about 15°) for more than 700 feet. In that distance the coal bed holds remarkably constant, ranging from a little less than 4 feet to 4 feet 3½ inches in thickness. Generally it is free from shale or clay partings, but near the mouth of the mine a small parting is present. The roof and floor are both composed of massive sandstone, which makes mining comparatively simple. Although the mine is located at the point where the strike changes abruptly, the coal does not appear to be materially disturbed by faults or minor folds.

The coal is of excellent appearance, hard and bright, and evidently belongs to the bituminous class.

Other coal beds occur in the same section, but they are either too small or too impure for commercial use.

Sloan mine.—This mine is located near the middle of sec. 17, T. 13 N., R. 6 E. The rocks are considerably disturbed by faults which cut them in various directions. Much of the exploratory work at this place has been wasted on account of failure to recognize these faults, and any permanent mine work to be successful must be so planned as not to be affected by them. Several coal beds are exposed, but no attempt was made to determine the total number. The most prominent, supposed to be the same as the Hopewell bed at the Hagan mine, has the following section:

Section of coal bed at Sloan mine.

	Ft.	in.
Coal	1	9
Shale		8½
Coal	1	3
	3	8½

Pina Vititos field.—Apparently the same beds are exposed in the Pina Vititos field as were seen at the Sloan and Hagan mines. The Hopewell bed has been extensively mined in the past and seems to run about 4 feet in thickness. A bed 12 or 15 feet below the Hopewell has the following section:

Section of coal bed in Pina Vititos field.

	Ft.	in.
Coal	1	1½
Shale	1	3½
Coal		7½
Shale		11½
Coal	1	6
	5	6

Analyses.—The chemical composition of the Hopewell coal is shown by the following analyses made from samples collected by the writer in the south end and in the middle of the field:

Analyses of coal from Una del Gato field.

[E. E. Somermeier, analyst.]

	South end of field.	Middle of field.
Laboratory No	1012	1013
Moisture	7.81	9.68
Volatile matter	44.72	42.32
Fixed carbon	41.80	41.36
Ash	5.67	6.64
Sulphur	.69	.66

It has also been tested by the owners, who report the following analyses, made at the Pittsburg Testing Laboratory (Limited).[a] The writer has no knowledge of how the sampling was done, nor of how the samples were handled afterwards. The analyses are given merely for what they are worth:

Analyses of coals from the Una del Gato field.

	Hagan mine.	Sloan mine.	Pina Vititos mine.
Moisture	6.25	7.28	9.03
Volatile matter	40.40	42.49	42.35
Fixed carbon	47.56	43.60	44.17
Ash	5.78	6.63	4.45
Sulphur	.62	.67	.66

[a] Unpublished private report of Charles R. Keyes.

COAL IN THE VICINITY OF FORT STANTON RESERVATION, LINCOLN COUNTY, N. MEX.

By Marius R. Campbell.

During the past year the writer made a hurried examination of the Fort Stanton Public Health and Marine-Hospital Service Reservation and immediate vicinity in search of coal. Although the work was rapidly done and only a small area examined, certain facts regarding the occurrence of coal in that field were determined which seem to be of sufficient importance to justify publication.

The Fort Stanton Reservation is located about 6 miles west of Lincoln, the county seat of Lincoln County, N. Mex. It occupies the valley of Bonito Creek, which heads in the White Mountains to the southwest, and it extends northward nearly to the foothills of the Capitan Range. Access to the reservation is had by wagon road from Roswell, on Pecos River, 50 miles to the east, or by a branch line of the El Paso and Southwestern System from Carrizozo on the west. This branch railroad was originally built to develop the coal mines at Capitan, but since the mines as well as the railroad have passed into the hands of the El Paso and Southwestern System, mining has been abandoned and train service has been all but discontinued. According to report, mining was stopped on account of the great number of dikes encountered and because the coal could not compete with that from the Dawson mines in Colfax County, which were acquired by the same company.

The geologic relations in the Capitan coal field are not easily made out, as the country is seamed and cut by dikes in all directions and by at least one fault of considerable proportions. The coal-bearing rocks of the field have been called Laramie, but apparently on no evidence except that they are probably Cretaceous in age and lie above the Benton (Colorado) shale. Fossils are not abundant in the coal field, but the writer made a small collection of fossil leaves from a sandstone bed closely underlying the coal at an abandoned mine about a mile west of the village of Capitan. The material was not sufficient for a final determination, but according to the following report of F. H. Knowlton is classed as probably of Laramie age:

From this small but interesting collection I have been able to identify the following forms with a considerable degree of certainty: *Cinnamomum affine* Lesq., *Platanus*

Raynoldsii? Newby, *Populus* sp.? cf. *P. melanarioides* Lesq. The most abundant form in the collection is the *Cinnamomum*, which appears to be the *C. affine* of Lesquereux, but the leaves are rather smaller than the normal leaves of that species and not all of them quite agree with the types. It may be that it is a new but closely related species, though if correctly determined—and I believe it is—it would indicate a Laramie age for the beds. The specimen identified with *Platanus Raynoldsii* is a mere fragment from the base of the leaf, but it can hardly be another species. The *Populus* is a smaller leaf than the type specimen of *P. melanarioides*, but is otherwise indistinguishable. My opinion is that the beds in question are Laramie in age.

The extent of these beds could not be determined, but from their widespread distribution on the summit northwest of Capitan and along Bonito Creek it seems that they must have a thickness of many hundreds of feet, possibly approaching 1,000 feet. In general they consist of sandstone and shale, the former buff or yellowish white, and the latter variegated in color, with reds and greens of common occurrence. Coal beds are present in this formation, but most of them seem to be small, having a thickness of only a few inches.

In the vicinity of Capitan there is at least one coal bed of workable thickness, which has been prospected along the outcrop from a point about 1½ miles southwest of the village northward for a distance of 2 or 3 miles. Many openings have been made and coal has been mined at various places along this line of outcrop. The two principal mines were known as Capitan Nos. 1 and 2. Mine No. 1 is located in sec. 4, T. 9 S., R. 14 E., and mine No. 2 in the E. ½ NE. ¼ sec. 8, T. 9 S., R. 14 E. All work is now abandoned except in mine No. 1, which is leased by local residents and in which a small amount of coal is being mined for home consumption.

The coal is bright and hard enough to stand transportation. No chemical analyses are available by which to determine its characteristics, but from physical appearance it should be classed undoubtedly as a bituminous coal. No measurements were made of the thickness of the bed in mine No. 1, but near the mouth of mine No. 2 the coal has the following section:

Section of Capitan coal bed in mine No. 2.

	Ft.	in.
Sandstone roof.		
Coal	1	7
Shale		4
Coal	3	6
	5	5

The fossil plants noted above were obtained from the vicinity of this mine. Both Nos. 1 and 2 are slope mines, the coal bed dipping about 4° to 8° SW.

As shown by the accompanying sketch map (fig. 5), the coal outcrops in a nearly north-south direction, approximately along the line between secs. 4–5 and 8–9. To the north it probably passes into

T. 8 S., R. 14 E., but its outcrop was not definitely located. South of mine No. 2 the outcrop can be followed for a distance of about a mile to a point where it is cut off abruptly by a fault which extends at least across parts of three tiers of townships. This fault passes about half a mile west of Capitan in a nearly north-south direction. A little south of the village it swings to the west and passes about 800 feet west of the west corner (No. 47) of the Fort Stanton Reservation. From this point it trends nearly southward for 2 miles and then swings to the southwest, crossing Bonito Creek just above the main road, about 2 miles east of Angus. From this point on Bonito Creek the

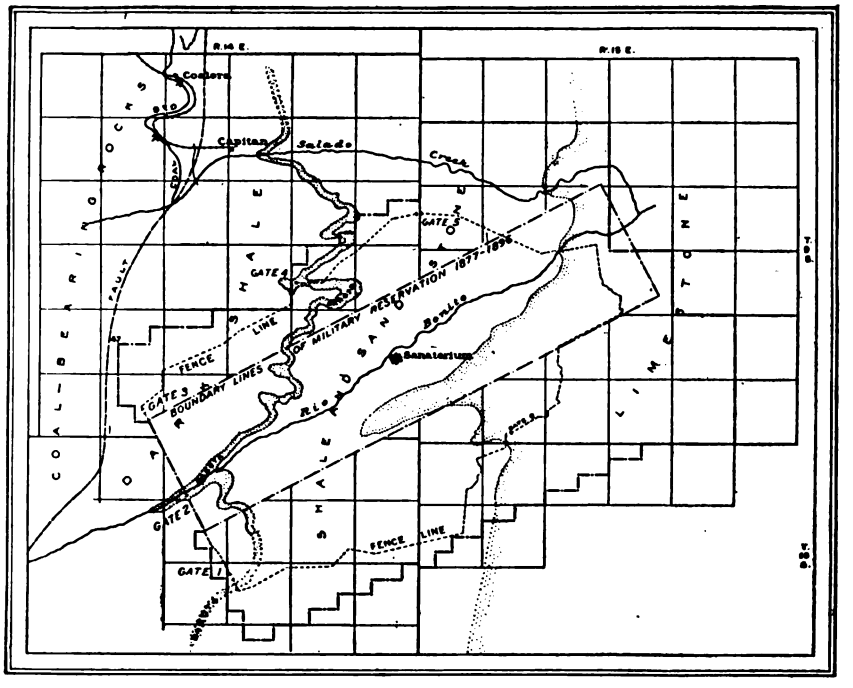

FIG. 5.—Geologic sketch map of Fort Stanton Reservation and vicinity, New Mexico.

fault trends to the southwest in the direction of Ruidoso, where coal of workable thickness is reported. It seems possible that the Capitan coal bed reappears near Ruidoso and that in the intermediate area it is so far below the surface as to be beyond reach.

Time did not permit an extended reconnaissance to determine the relation of the rocks on the two sides of this fault, but enough was seen to warrant the belief that the beds on the east side have been raised relative to the coal-bearing rocks on the west side. The amount of displacement could not be determined. It seems probable, however, that it is not great, and that in the vicinity of Capitan it may be less than 200 feet.

The rocks exposed east of the fault show the following section, the thicknesses being estimated:

Geologic section in Fort Stanton Reservation.

	Feet.
1. Sandstone, massive, yellowish brown; highest rock east of fault; caps mesa southwest of Capitan, possibly base of Laramie....	100
2. Shale, mainly dark, almost black at base (fossiliferous).....	500
3. Sandstone, massive, traces of plant stems.....	100
4. Shale and sandstone, the former variegated.....	300
5. Limestone, gray (sparingly fossiliferous).....	700
6. Shale, variegated.	

The only fossil found in No. 1 is an oyster, which is not distinctive, but, according to T. W. Stanton, may be of Montana age. A few fossils were found at the base of No. 2, at the southwest corner of sec. 22, T. 9 S., R. 14 E., and also near the upper (No. 2) gate of the reservation in the SW. ¼ sec. 9, T. 10 S., R. 14 E. Doctor Stanton reports on these as follows:

The lot from near the upper gate of the Fort Stanton Reservation consists of dark calcareous shale, with many specimens of *Inoceramus labiatus* Schloth. and some imperfect imprints of two species of ammonites, probably belonging to the genus *Prionotropis*. The horizon is in the Benton group.

The dark shale identified by Doctor Stanton as Benton rests directly upon a massive sandstone, supposed to be Dakota, that is well exposed in the gorge of Salado Creek, one-half mile east of Capitan, where it dips to the west and passes under the dark shale forming the valley in which the village is located. From its outcrop on Salado Creek the sandstone swings to the south and enters the reservation in the vicinity of gate No. 4. It is not well exposed on the road from Fort Stanton to gate No. 4, but can be seen in every side ravine entering Bonito Creek from the west above the sanatorium. This bed crosses Bonito Creek about a mile below gate No. 2 and then passes out of the reservation between gate No. 2 and the south corner.

Traces of coal were found in this sandstone, but nothing of economic importance. Toward the base the massive sandstone is replaced by thinner-bedded sandstones accompanied by shale. At the time of the visit these lower beds were regarded as part of the same formation, but on comparison with other sections in the Territory it seems probable that the beds below this massive sandstone are of Morrison age, and consequently are not directly related to the Dakota sandstone.

The shale and sandstone beds of the supposed Morrison formation rest upon a great mass of gray limestone, which covers the eastern half of the reservation and which is supposed to be of Carboniferous age, although no fossils were obtained by which to determine this point. The limestone is apparently underlain by reddish shale, but the writer had no opportunity of examining this part of the sections, and consequently knows little regarding it, except what could be seen from a distance.

COAL OF STONE CANYON, MONTEREY COUNTY, CAL.

By Marius R. Campbell.

In Contributions to Economic Geology for 1905, Ralph Arnold published a brief account [a] of the coal bed showing in Stone Canyon, in the southeast corner of Monterey County, Cal. From his description the coal appears to be exceptionally good for this region; and so the writer, during the last year, made a brief examination of the mine and sampled the coal for chemical analysis.

As noted by Arnold, the coal is unique as regards its geologic age, but the presence a few feet above the coal bed of a richly fossiliferous sandstone fixes its age as Lower Miocene beyond the possibility of a doubt.

The coal bed lies very close to the contact between the Miocene sandstone and the Franciscan chert and serpentine. The younger beds rest in a syncline upon the older rocks, and considerable time and money have been spent searching for the outcrop of this coal bed on the other limb of the syncline, along the contact of what has always been supposed to be the same formations. The chief value of Arnold's contribution is that he has shown conclusively that the coal-bearing sandstones are overlain unconformably by the Upper Miocene sandstones and shales, and that it is the latter rocks which are in contact with the Franciscan on the northeastern limb of the trough. According to this determination the horizon of the coal bed is not present in that region, and consequently search for it in the past has been unrewarded, and in the future will yield only negative results.

At the time of Arnold's visit it was supposed that the clay which lies below the coal and which is commonly regarded as forming the foot wall was residual clay, resulting from the decay of the serpentine rocks (Franciscan). Since t hat time, however, a crosscut or tunnel has been driven from the coal bed for a distance of 50 feet toward the Franciscan; but the only rocks cut in this tunnel are clay and greenish sandstones closely resembling the Lower Miocene sandstone as seen in the canyon just above the mine. Not only do these rocks appear to be part of the coal-bearing Miocene, but, so far as the writer could determine, they do not show any evidence of

[a] Coal in the Mount Diablo Range, Monterey County, Cal.: Bull. U. S. Geol. Survey No. 285, 1906, pp. 223-225.

shore conditions and material directly derived from the Franciscan rocks. In view of this development the coal bed can not be regarded as resting directly upon the Franciscan, nor can the contact between the two rock masses be regarded as undoubtedly that of nonconformity, due to overlap.

This conclusion is of the utmost importance in the commercial development of the mine, for the reason that if the coal was deposited upon the uneven floor of the old Franciscan land mass the coal bed would be subject to abrupt and extreme variations in thickness, and consequently would be irregular in its geographic extent. If, however, at least 50 feet of material was laid down before the coal was deposited, the latter is likely to be fairly regular in thickness, and mining operations can be carried on with the prospect of finding the bed of workable thickness over a rather large area.

The coal bed is developed by a mine in sec. 14, T. 22 S., R. 13 E., which consists of two openings—one a slope 350 feet in depth going down toward the northeast nearly on the coal bed, which dips at an angle of 63°, and the other a drift southeast of the creek, where the coal bed stands nearly vertical. The mouth of this drift is 1,500 feet southeast of the slope and it has been driven in on the coal bed in a southeasterly direction for a distance of 3,000 feet. From the bottom of the slope gangways have been driven for about 2,000 feet and a drill has been sunk on the bed for a distance of 250 feet below the floor of the gangway. Throughout the extent of the developed mine the coal bed holds a fairly uniform thickness, but accurate measurements were difficult to obtain, as the lower part of the bed was not always removed. The gangways are in general from 10 to 12 feet wide, and they rarely reach both the top and bottom of the bed. Tests at various places in the mine have shown from 14 to 18 feet of coal with an average thickness of about 15 feet.

On the surface the coal is exposed at only a few places, but extensive prospecting has showed, according to the owners, that the coal bed extends in a northwest-southeast direction for a distance of nearly 8 miles. The prospect pits are now caved, so that it is impossible to verify this statement. Actual mining has extended for a distance of about 5,000 feet, and in that distance there is no indication of material variation in the thickness of the bed.

Two samples, A and B, were taken for chemical analysis. Sample A represents the coal where it is slightly damp and sample B where it is exceedingly dry.

Analyses of coal from Stone Canyon.

[F. M. Stanton, analyst.]

	As received.		Air dried.	
	A.	B.	A.	B.
Laboratory No	3772.	3773.	3772.	3773.
Air-drying loss	3.50	2.20	.....	.....
Moisture	7.13	6.95	3.76	4.86
Volatile matter	44.47	46.69	46.08	47.74
Fixed carbon	37.03	40.13	38.37	41.03
Ash	11.37	6.23	11.79	6.37
Sulphur	4.60	4.17	4.77	4.26
Hydrogen	.....	6.28	.....	6.18
Carbon	.....	66.01	.....	67.50
Nitrogen	.....	1.17	.....	1.19
Oxygen	.....	16.14	.....	14.50
British thermal units	.....	12,447	.....	12,727

This part of Monterey County is semiarid, and the coal, so far as the bed has been followed, carries very little water. This is especially true of the drift, which is drained below into the 300-foot level of the slope. In this opening the coal is as dry and brittle as if it had been kiln dried, but in the slope there is a small amount of water.

The coal is hard and generally of a dull luster, but there are scattered bands of bright coal. Cleavage is not extensively developed in the coal, but as a rule the large blocks are bounded by joint planes. The coal has a brown streak, and on this account has generally been classed as a lignite. The writer, however, is not disposed to regard this characteristic as distinctive of lignite, for the reason that many coals which give such a streak are to all intents and purposes bituminous coals. So far as the writer has observed, weathering is a better criterion for distinguishing between bituminous and subbituminous [a] coals. One of the distinguishing features of all lignites and subbituminous coals is the breaking up of the coal and loss of moisture on drying. In the lower grades of lignite this is so pronounced that lumps go to pieces in a few days or even hours, in much the same manner as the slaking of lime. In this breaking up the fractures are very irregular, with no tendency to follow certain planes, as is the case with bituminous coal. The latter may break into as fine fragments as the lignites, but all the particles are rudely prismatic, due to the cleavage developed in the coal.

The Stone Canyon coal does not show the characteristic slaking of lignite, nor does it weather readily on exposure to the atmosphere. At present the mine has no railroad connection, and it is kept in operation on a small scale pending such connection. Several hundred tons of lump coal have been corded up near the engine house, and, according to report, have been standing in this position for two or three years without showing any appreciable tendency to disintegrate. Minute

[a] The name subbituminous has been adopted by the United States Geological Survey for the class of coals generally called "black lignites," or "lignitic coals" to distinguish them from the true, brown, woody lignites.

checks resembling lignite fractures appear on many of the blocks, but they have not developed sufficiently to cause the blocks to crumble. On chemical composition alone it is impossible to classify this coal satisfactorily by any of the schemes so far proposed, but on physical properties alone the writer regards it as a bituminous coal.

The most striking characteristic of the coal as shown by chemical analyses is the heavy percentage of volatile matter as compared with the fixed carbon. This indicates a rich gas-making coal, and, were it not for the heavy percentage of sulphur, it could doubtless be used to advantage in the manufacture of illuminating gas. The heating properties of the coal are excellent, running as high as 12,727 British thermal units in the air-dried sample. This is considerably better than most of the subbituminous coals of the Pacific coast or even some of the better grades of coal of Wyoming.

The hardness and the freedom from slaking make this an excellent shipping coal, and, so far as the writer's experience goes, it is the best grade of coal on the Pacific coast south of Washington.

THE PRESENT STATUS OF THE PRODUCER-GAS POWER PLANT IN THE UNITED STATES.

By Robert Heywood Fernald.

INTRODUCTION.

Recent developments indicate very positively that two factors will be of great importance in the economical production of power for manufacturing and transportation purposes. These two factors are the replacing to a marked extent of the steam boiler and steam engine by producer-gas plants, with their accompanying internal-combustion engines, and the centralization of power production and distribution.

RAPID DEVELOPMENT OF THE GAS ENGINE.

It was only during the latter part of the nineteenth century that the gas engine came into common use, and although many types have been devised within the last twenty or thirty years it is only within the past five or six years that large engines have been constructed. This development started eight or ten years ago in Germany, Belgium, and England, but marked progress has been limited to the last six years.

For a long time the natural fuel of these internal-combustion engines was city gas, but this was too expensive except for engines of small capacity. It was seldom found economical to operate units of more than 75 horsepower with this fuel. Cheap gas was essential for the development of the gas engine, but the early attempts to produce cheap gas were somewhat discouraging, and for a time the probability that the gas engine would encroach to any extent on the field occupied by the steam engine seemed very remote. The theoretical possibilities of the internal-combustion engine operating on cheap fuel promised so much however that the practical difficulties were rapidly overcome, with the result that the internal-combustion engine is rapidly becoming a serious rival of the steam engine in many of its applications.

The development of large-sized gas engines within the last few years has been exceedingly rapid. It was only seven years ago that

a 600-horsepower engine exhibited at the Paris Exposition was regarded as a wonder, but to-day four-cycle, twin-tandem, double-acting engines run as high as 6,000 horsepower.

DEVELOPMENT OF THE GAS PRODUCER FOR POWER PURPOSES.

The rapid advance of the large gas engine has been made possible by improvements in the production of cheap gas directly from fuel through the aid of the gas producer. An early form of producer introduced in Europe, and now in very general use both abroad and at home, is known as the suction producer, a name suggested by the fact that the engine develops its charge of gas in the producer by means of its own suction stroke. Although many producers of this type are now used, most of them are small, not exceeding 150 horsepower. As far as known the first suction producer operated in the United States was installed in 1903, although producers of other types were tried in this country as early as 1896. A serious limitation to the utility of the suction producer has been the fact that, owing to the manner of generating the gas, no tarry fuels could be used, a restriction that prevented the use of bituminous coals, lignites, peats, and other like fuels. The fuels in most common use for producers of this kind are charcoal, coke, and anthracite coal, although attempts are being made so to construct suction plants that they can be operated on bituminous or tarry coals.

The pressure producer was devised to meet a demand for the concentration of power in large units, to replace a greater number of engines of smaller power. By this producer the gas is generated under slight pressure, due to the introduction of an air and steam blast, and stored in a holder until it is required for the engine. As the gas may thus be stored before passing to the engine, and as it is produced under pressure and its generation does not depend on the suction stroke of the engine, tar and other impurities may be removed from it by devices that permit the use of bituminous coal and lignite. In the progress of invention in this field the pressure producer was closely followed by the down-draft producer, which fixes the tar as a permanent gas and therefore completely uses bituminous coal and lignite.

Pressure and down-draft producers have been in operation for the last few years, but the fuel used in most of them has been anthracite coal. Some plants, however, have used a few well-tried bituminous coals known to be especially free from sulphur, ash, and tarry matter. It remained for the United States Geological Survey, in its testing plant at St. Louis, to attempt the use of any and all bituminous coals, lignites, and peats, without reference to the amount of sulphur or tarry matter they contained. It is gratifying to note that every coal received has been run through the producer and that the results have been more than satisfactory.

TESTS MADE BY THE UNITED STATES GEOLOGICAL SURVEY.

DESCRIPTION OF PLANT.

In view of the possibility that the gas engine, with its gas producer, may displace the steam engine, the problem here considered has become so important that the Government made special provision for producer-gas tests at its fuel-testing plant installed in connection with the Exposition at St. Louis. These tests have furnished valuable data on the relative consumption of coal per horsepower per hour when used by the steam plant and by the gas plant.

The steam plant with which tests were made consists of two 210-horsepower Heine boilers, furnishing steam to a 250-horsepower, simple, noncondensing Corliss engine, which was belted to a Bullock electric generator.

The producer-gas plant is a Taylor pressure gas producer No. 7, of 250-horsepower capacity. Connected with the producer is the usual apparatus for cleansing and storing the gas before it is delivered to the engine—the economizer, scrubber, tar extractor, purifier, and holder.

The gas engine is of the three-cylinder, vertical, Westinghouse type, with cylinders of 19-inch diameter and 22-inch stroke, rated at 235 brake horsepower on producer gas. The engine was belted to a 6-pole 175-kilowatt Westinghouse direct-current generator. The load on the generator was controlled by a water rheostat, especially constructed for the purpose, through which also the energy developed was dissipated.

DETAILS OF TESTS.

By means of this producer-gas plant, which was installed in 1904, 162 tests have been made. The fuels used were bituminous coals, lignites, and peats from 26 different States, as indicated below:

Fuels tested at gas-producer plant of the United States Geological Survey, St. Louis, Mo.

BITUMINOUS COALS.	
Alabama	3
Arkansas	2
Illinois	29
Indiana	15
Indian Territory	2
Iowa	1
Kansas	2
Kentucky	5
Missouri	1
New Mexico	3
Ohio	10
Pennsylvania	13
Tennessee	8
Utah	1
Virginia	5
Washington	1
West Virginia	14
Wyoming	5
	120

SUBBITUMINOUS [a] COALS.	
California	1
Colorado	1
Montana	3
Washington	3
Wyoming	1
	9

[a] The term subbituminous has been adopted by the United States Geological Survey for the class of coal generally called "black lignite."

LIGNITES.

Arkansas	1
North Dakota	4
Texas	4
	9

MISCELLANEOUS FUELS.

Argentine coal	1
Brazil coal	1
California coal and "front end" cinders	2
Florida peat	1
Massachusetts peat	1
Rhode Island anthracite	1
Virginia pea semianthracite	1
Coke breeze	1
Miscellaneous refuse	1
Coke	1
	11

COALS (DUPLICATE TESTS).

Illinois	2
Indiana	4
Kansas	1
Ohio	1
Pennsylvania	2
Tennessee	1
West Virginia	1
	12

LIGNITE (DUPLICATE TEST).

North Dakota	1

The results of these tests, as given in the accompanying table, have been subjected to absolutely no refinements. With the possible exception of two or three coals, only one test has been made on each sample, and the result of each test has, to a great extent, depended on the ability of the producer operator to become familiar with the method of handling a given coal during a period of eight or ten hours preceding the official test.

It should also be borne in mind that all of the tests, whether on bituminous coal, lignite, or peat, have been made in a producer of one size and type—a type designed primarily for use with anthracite coal—and that it has been imperative that the test be made and the required power generated without regard to the proper relations between the gas-producing qualities of the coal and the fuel-bed area. The tests have been conducted under the restrictions of steady load on the engine (235 brake horsepower), and not with a view to determining the maximum power-producing quality of the coal. Despite this restriction the general conclusions are regarded as sufficiently significant for presentation, although they may be modified by later investigations.

Summary of results of producer-gas tests at St. Louis.

Name of sample.	Location of mine.	Size or condition.	Equivalent pounds of coal used per hour.	British thermal units.		Equivalent pounds of coal as fired per horsepower hour.			
				Per pound of coal as fired.	Per cubic foot of standard gas.	Per electrical horsepower.		Per brake horsepower.	
						Available for outside purposes.	Developed at switchboard.	Available for outside purposes.	Developed at engine.
Alabama No. 2	Carbon Hill	Lump	341.4	12,865	149.2	1.77	1.71	1.51	1.45
Alabama No. 4	Belle Ellen	Run of mine	265.2	12,953	152.0	1.45	1.36	1.23	1.16
Alabama No. 6	Dolomite	do	196.6	14,170	143.7	1.02	0.99	0.87	0.84
Arkansas No. 7	Midland	Lump	280.5	12,773	125.5	2.24	2.04	1.90	1.74
Arkansas No. 8	Spadra	4-inch	358.1	12,546	130.0	2.13	2.02	1.81	1.72
Arkansas No. 10	Lester [a]	Lump	523.4	6,356	125.3	4.41	4.07	3.75	3.45
Brazil No. 1	Porto Alegre	Run of mine	369.2	9,058	130.9	2.88	2.60	2.45	2.21
California No. 1	Tesla [b]		597.3	8,530	158.3	3.06	2.88	2.60	2.45
Colorado No. 1	Lafayette [b]	Lump	428.4	9,767	149.0	2.30	2.14	1.95	1.82
Florida No. 1	Orlando [c]	Bricks	620.6	8,127	175.2	3.16	3.03	2.69	2.57
Illinois No. 3	Marion	Run of mine	386.0	12,046	154.8	2.01	1.93	1.70	1.64
Illinois No. 4	Troy	2-inch +	398.2	11,237	151.5	2.11	2.01	1.79	1.71
Illinois No. 6	Coffeen	Lump	418.2	10,141	152.0	2.14	2.02	1.82	1.72
Illinois No. 7	Collinsville	½-inch −	683.8	9,360	109.3	5.25	4.94	4.46	4.20
Do	do	1-inch +	492.1	9,970	138.6	2.52	2.41	2.14	2.05
Do	do	Slack	508.5	9,958	120.2	3.12	2.91	2.65	2.47
Illinois No. 8	Paisley	Nut	411.5	10,680	147.0	2.08	1.98	1.77	1.68
Illinois No. 9	Staunton	Lump	418.1	10,854	143.7	2.11	2.01	1.79	1.71
Illinois No. 10	West Frankfort	Slack	329.5	11,768	140.7	1.69	1.59	1.44	1.35
Illinois No. 11	Carterville	Egg	305.8	12,004	173.4	1.56	1.46	1.33	1.24
Do	do	5 washed	595.1	10,865	109.8	3.66	3.42	3.13	2.91
Do	do	3 washed	277.1	12,361	146.1	1.47	1.38	1.25	1.17
Do	do	do	277.7	12,474	154.9	1.46	1.37	1.24	1.16
Illinois No. 13	Benton	Egg	362.6	11,686	156.8	1.84	1.74	1.56	1.48
Illinois No. 14	Springfield	Lump	356.0	10,679	150.6	1.90	1.79	1.61	1.52
Illinois No. 15	Centralia	do	360.2	10,964	142.9	1.91	1.80	1.63	1.53
Illinois No. 16	Herrin	do	364.1	11,920	149.5	1.91	1.81	1.62	1.54
Illinois No. 18	Lasalle	do	350.3	11,039	147.7	1.85	1.74	1.57	1.48
Illinois No. 19	Zeigler	3-inch +	294.8	11,871	164.1	1.55	1.47	1.32	1.25
Do	do	Run of mine	314.4	11,493	137.8	2.40	2.23	2.04	1.90
Illinois No. 21	Troy	Lump	396.4	10,528	156.1	2.18	2.07	1.85	1.76
Illinois No. 24	New Baden	do	311.8	10,958	160.5	1.63	1.55	1.39	1.32
Illinois No. 23	Donkville	5-inch	379.1	10,667	147.9	2.02	1.91	1.71	1.63
Do	do	Slack	374.9	10,804	145.0	2.17	2.07	1.85	1.76
Illinois No. 22	Maryville	Lump	368.3	10,735	159.6	2.00	1.88	1.70	1.59
Illinois No. 25	Germantown	do	337.7	10,733	168.0	1.78	1.68	1.51	1.43
Illinois No. 26	Lincoln	Run of mine	348.4	10,013	147.2	2.13	2.00	1.81	1.70
Illinois No. 27	Auburn	do	347.4	10,485	122.5	3.06	2.78	2.60	2.36
Illinois No. 29	Livingston	do	370.3	10,719	141.2	2.00	1.91	1.70	1.62
Illinois No. 30	Shiloh	Washed	339.5	12,188	154.4	1.78	1.71	1.51	1.45
Indiana No. 1	Mildred	Run of mine	434.6	11,534	153.7	2.31	2.17	1.96	1.85
Indiana No. 2	Boonville	do	370.1	11,822	139.6	2.36	2.22	2.01	1.89
Indiana No. 3	do	Nut and slack.	372.5	11,417	137.2	2.09	1.97	1.78	1.67
Indiana No. 5	Hymera	Run of mine	427.5	11,052	136.7	2.29	2.15	1.95	1.83
Do	do	do	304.4	11,520	145.0	1.62	1.51	1.37	1.28
Indiana No. 6	do	do	387.3	11,158	150.9	2.05	1.94	1.74	1.65
Indiana No. 7	Littles	1¼-inch +	326.5	11,810	158.5	1.74	1.65	1.47	1.40
Indiana No. 8	Tére Haute	Lump	322.7	11,687	151.5	1.70	1.61	1.45	1.37
Indiana No. 9	Macksville	1¼-inch +	360.7	11,246	151.8	1.94	1.84	1.65	1.57
Indiana No. 11	Dugger	Lump	346.8	11,581	147.1	1.83	1.73	1.56	1.47
Indiana No. 12	Hartwell	Run of mine	364.4	11,146	149.4	1.97	1.87	1.67	1.59
Indiana No. 13	Terre Haute	do	333.5	10,924	131.9	2.21	2.09	1.88	1.77
Do	do	do	304.9	11,408	148.0	1.68	1.61	1.43	1.37
Indiana No. 14	Seelyville	do	343.4	11,146	154.1	1.91	1.81	1.62	1.54
Indiana No. 15	Linton	do	314.0	11,651	144.1	1.75	1.66	1.48	1.41
Do	do	do	302.6	11,651	145.7	1.65	1.56	1.40	1.33
Indiana No. 16	do	do	345.8	11,592	136.7	2.06	1.95	1.75	1.66
Indiana No. 18	Winslow	Lump	309.3	12,031	154.7	1.67	1.59	1.42	1.35
Do	do	do	351.1	11,952	152.6	1.88	1.79	1.60	1.52
Indian Territory No. 1.	Henryetta	1¾-inch +	392.7	12,787	159.2	2.00	1.92	1.71	1.64
Indian Territory No. 4.	Lehigh	1-inch +	312.5	10,364	161.1	1.66	1.57	1.41	1.33
Iowa No. 2	Marion County	Run of mine	408.4	8,735	160.2	2.19	2.07	1.86	1.76
Kansas No. 5	West Mineral	⅝-inch +	338.4	12,836	167.2	1.76	1.69	1.50	1.44
Do	do	do	325.3	12,967	128.9	1.65	1.57	1.40	1.33
Kansas No. 6	Jewett	Lump	349.4	11,470	155.2	1.84	1.76	1.56	1.49

[a] Brown lignite. [b] Black lignite. [c] Machined peat.

Summary of results of producer-gas tests at St. Louis—Continued.

Name of sample.	Location of mine.	Size or condition.	Equivalent pounds of coal used per hour.	British thermal units.		Equivalent pounds of coal as fired per horsepower hour.			
				Per pound of coal as fired.	Per cubic foot of standard gas.	Per electrical horsepower		Per brake horsepower.	
						Available for outside purposes.	Developed at switchboard.	Available for outside purposes.	Developed at engine.
Kentucky No. 1	Straight Creek	Egg	276.7	14,270	166.5	1.49	1.41	1.26	1.19
Kentucky No. 3	Earlington	Run of mine	410.8	12,283	155.9	2.16	2.05	1.86	1.75
Kentucky No. 5	Big Black Mountain.	do	274.4	13,984	163.2	1.47	1.39	1.25	1.18
Kentucky No. 6	Paintsville	do	265.6	13,747	176.0	1.42	1.33	1.20	1.13
Kentucky No. 7	Central City	1½-inch +	322.8	11,986	153.7	1.75	1.65	1.49	1.40
Missouri No. 2	Bevier	Run of mine	384.5	10,505	140.0	2.07	1.94	1.76	1.65
Montana No. 1	Red Lodge	4 washed	506.8	10,575	160.8	2.65	2.54	2.26	2.16
Montana No. 2			424.6	10,478	147.5	2.34	2.25	1.99	1.91
Montana No. 3			347.2	10,685	181.5	1.80	1.74	1.53	1.48
New Mexico No. 3	Van Houten	Run of mine	275.7	11,425	155.1	1.47	1.39	1.25	1.18
New Mexico No. 4	Brilliant	do	287.5	12,501	135.3	1.62	1.52	1.38	1.29
New Mexico No. 5	Blossburg	do	298.1	12,542	159.6	1.60	1.51	1.36	1.29
North Dakota No. 1	Lehigh [a]	Lump	559.5	6,970	160.6	3.04	2.82	2.58	2.40
North Dakota No. 2	Williston [a]	do	510.0	6,802	188.5	4.07	3.80	3.47	2.23
Do	do.[a]	do	552.1	7,326	164.1	2.97	2.83	2.53	2.40
Do	do.[a]	do	571.6	6,739	145.0	2.97	2.87	2.53	2.44
North Dakota No. 3	Wilton [a]	do	632.8	7,279	158.9	3.42	3.24	2.92	2.75
Ohio No. 3	Shawnee	Washed	303.4	12,200	156.1	1.62	1.51	1.37	1.28
Ohio No. 4	Bradley	Lump	270.4	13,158	148.8	1.41	1.34	1.20	1.14
Ohio No. 5	Rush Run	Nut	254.0	13,414	152.3	1.34	1.26	1.13	1.07
Ohio No. 6	Neff's	Run of mine	254.2	13,035	163.4	1.36	1.30	1.16	1.10
Ohio No. 7	Danford	Lump	331.0	12,841	156.2	1.76	1.67	1.50	1.42
Ohio No. 8	Bixie	Run of mine	309.1	11,302	170.2	1.67	1.56	1.42	1.32
Ohio No. 9	Clarion	Lump	277.7	12,492	154.6	1.51	1.43	1.28	1.21
Ohio No. 10	Mineral City	do	268.7	12,805	165.6	1.40	1.35	1.19	1.15
Ohio No. 11	Flushing	do	296.8	12,287	165.2	1.55	1.49	1.32	1.26
Ohio No. 12	Bellaire	Run of mine	335.5	12,933	164.8	1.77	1.69	1.50	1.43
Do	do	do	309.3	12,739	164.6	1.62	1.56	1.38	1.32
Pennsylvania No. 4	Greensburg	Lump	276.6	13,518	140.6	1.49	1.42	1.27	1.21
Pennsylvania No. 5	Ellsworth	Nut	259.0	13,613	149.3	1.37	1.28	1.16	1.09
Pennsylvania No. 6	East Millsboro	Run of mine	294.8	13,921	126.6	1.63	1.51	1.38	1.28
Do	do	do	238.3	13,025	146.4	1.30	1.23	1.10	1.04
Pennsylvania No. 7	Ligonier	do	284.5	13,223	139.4	1.79	1.68	1.52	1.42
Pennsylvania No. 8	Ehrenfeld	do	240.0	14,353	133.0	1.35	1.28	1.15	1.09
Pennsylvania No. 10.	Bruce	¾-inch	258.6	13,606	159.5	1.38	1.32	1.18	1.12
Pennsylvania No. 11.	Charleroi	Run of mine	265.0	13,775	146.4	1.66	1.55	1.41	1.32
Pennsylvania No. 12.	Atcheson	do	240.2	13,622	147.5	1.28	1.23	1.09	1.05
Pennsylvania No. 13.	Creighton	do	274.5	12,816	153.0	1.49	1.42	1.26	1.21
Do	do	do	255.8	13,181	144.9	1.36	1.30	1.16	1.10
Pennsylvania No. 15.	Wehrum	do	263.3	13,712	144.4	1.43	1.37	1.22	1.17
Pennsylvania No. 16.	Hastings	do	223.0	13,318	149.5	1.17	1.12	0.99	0.95
Pennsylvania No. 17.	White	do	279.9	12,798	141.2	1.55	1.49	1.31	1.26
Pennsylvania No. 22.	Greensburg	do	248.5	13,311	145.6	1.31	1.26	1.11	1.07
Tennessee No. 1	Fork Ridge	do	262.9	12,749	154.5	.....	1.56	.....	1.32
Tennessee No. 2	Gotliffe	do	248.9	13,882	167.9	1.30	1.24	1.11	1.05
Tennessee No. 3	do	do	281.3	13,156	159.7	1.50	1.40	1.27	1.19
Tennessee No. 4	Oliver Springs	do	263.9	13,379	161.7	1.54	1.45	1.31	1.23
Tennessee No. 5	Petros	do	281.2	13,442	142.1	1.61	1.51	1.37	1.28
Tennessee No. 6	Waldencia	do	291.2	11,621	133.3	2.02	1.87	1.72	1.59
Tennessee No. 7	Wilder	do	313.6	12,602	154.6	1.74	1.63	1.48	1.38
Tennessee No. 8	Clifty	do	243.9	13,471	147.4	.....	1.69	.....	1.43
Do	do	do	291.3	13,459	157.5	1.58	1.48	1.34	1.26
Texas No. 1	Crockett [a]	do	660.0	7,267	169.7	3.53	3.34	3.00	2.83
Texas No. 2	Hoyt [a]	do	519.5	7,348	156.2	2.74	2.58	2.33	2.20
Texas No. 3	Olsen [a]	do	549.4	7,603	171.8	2.90	2.75	2.47	2.33
Texas No. 4	Hoyt [a]	do	529.8	7,448	156.1	2.87	2.74	2.43	2.33
Utah No. 1	Price	do	302.0	13,212	171.4	1.55	1.46	1.31	1.24
Virginia No. 1	Crab Orchard	do	300.2	13,324	164.4	1.61	1.53	1.37	1.30

[a] Brown lignite.

Summary of results of producer-gas tests at St. Louis—Continued.

Name of sample.	Location of mine.	Size or condition.	Equivalent pounds of coal used per hour.	British thermal units.		Equivalent pounds of coal as fired per horsepower hour.			
				Per pound of coal as fired.	Per cubic foot of standard gas.	Per electrical horsepower.		Per brake horsepower.	
						Available for outside purposes.	Developed at switchboard.	Available for outside purposes.	Developed at engine.
Virginia No. 2	Crab Orchard	Run of mine	272.7	14,080	169.0	1.47	1.38	1.25	1.17
Virginia No. 3	Toms Creek	Lump	236.7	14,643	156.4	1.29	1.21	1.10	1.03
Virginia No. 4	Darby	do	257.0	14,470	167.2	1.38	1.31	1.17	1.11
Virginia No. 5	Blacksburg	Pea	287.3	12,159	160.7	1.49	1.44	1.27	1.22
Virginia No. 6	Richlands	Run of mine	240.8	13,351	138.1	1.29	1.25	1.09	1.06
Washington No. 1	Renton		496.3	9,787	145.9	3.71	3.44	3.15	2.93
Do	do		440.7	9,680	159.2	3.03	2.82	2.57	2.40
Do	do		506.0	9,634	144.1	2.73	2.59	2.32	2.20
Washington No. 2	Roslyn	Lump	281.8	12,218	168.6	1.52	1.44	1.29	1.22
West Virginia No. 1	Kingmont	Run of mine	320.6	14,166	144.4	1.69	1.60	1.43	1.36
West Virginia No. 4	Kingwood	do	262.8	13,918	143.2	1.39	1.32	1.18	1.12
West Virginia No. 7	Sun	do	299.2	14,283	154.2	1.59	1.50	1.35	1.28
West Virginia No. 8	Ansted	do	364.7	14,168	155.1	1.92	1.82	1.63	1.55
West Virginia No. 9	Powellton	do	328.9	14,195	151.0	1.76	1.64	1.49	1.39
Do	do	do	284.8	14,224	160.5	1.51	1.43	1.28	1.21
West Virginia No. 12.	Big Sandy	do	304.9	14,614	142.5	1.59	1.53	1.35	1.30
West Virginia No. 13.	Page	do	208.0	14,674	139.2	1.10	1.04	0.93	0.88
West Virginia No. 14.	do	do	220.6	14,488	147.0	1.15	1.10	0.98	0.93
West Virginia No. 16.	Monongah	Nut	277.5	13,882	156.1	1.49	1.40	1.26	1.19
West Virginia No. 18.	Glen Alum	Run of mine	238.0	14,152	158.9	1.27	1.20	1.08	1.02
West Virginia No. 20.	Acme	do	257.3	13,948	156.3	1.39	1.31	1.18	1.11
West Virginia No. 25.	Charleston	Lump	273.0	13,288	171.6	1.42	1.37	1.21	1.17
Wyoming No. 2	Cambria	Run of mine	459.8	9,650	151.0	2.49	2.28	2.11	1.94
Do	do	do	440.2	9,853	146.6	2.40	2.28	2.05	1.94
Wyoming No. 3	Aladdin	do	394.5	9,338	160.9	2.19	2.04	1.86	1.74
Wyoming No. 4	Hanna	do	438.2	10,755	151.6	2.38	2.24	2.02	1.91
Wyoming No. 6	Kemmerer	do	474.9	10,460	171.8	2.52	2.38	2.14	2.02

RELATIVE RESULTS OF STEAM AND PRODUCER-GAS TESTS.

In considering the relation between the economic results of plants of the two types under discussion, namely, steam and producer-gas, the fact should be remembered that to-day, in the ordinary manufacturing plant operated by steam power, less than 5 per cent of the total energy in the fuel consumed is available for useful work at the machine.

In that connection it is of interest and value to glance at the possibilities of the best designed and most skillfully operated commercial plant now in use. The data concerning the steam plant selected for this determination are derived from a table prepared by Mr. Stott, superintendent of motive power, Interborough Rapid Transit Company, New York City, which, as Mr. Stott says,[a] shows "the losses found in a year's operation of what is probably one of the most effi-

[a] Stott, H. G., Power Plant Economics: Trans. Am. Inst. Elec. Eng., 1906.

cient plants in existence to-day, and, therefore, typical of the present state of the art."

Average losses in steam plant of the Interborough Company in converting 1 pound of coal, containing 12,500 British thermal units, into electricity.

	British thermal units.	Per cent.
Loss by friction	138	1.1
Loss in exhaust	7,513	60.1
Loss in pipes and auxiliaries	275	2.2
Loss in boiler	1,000	8.0
Loss in stack	1,987	15.9
Loss in ashes	300	2.4
Total losses	11,213	89.7
Energy utilized	1,287	10.3
	12,500	100.0

Mr. Stott further presents a table showing the thermal efficiency of producer-gas plants, concerning which he says:

The following heat balance is believed to represent the best results obtained in Europe and the United States up to date in the formation and utilization of producer-gas.

Average losses in a producer-gas plant in the conversion of 1 pound of coal, containing 12,500 British thermal units, into electricity.

	British thermal units.	Per cent.
Loss in gas producer and auxiliaries	2,500	20.0
Loss in cooling water in jackets	2,375	19.0
Loss in exhaust gases	3,750	30.0
Loss in engine friction	813	6.5
Loss in electric generator	62	0.5
Total losses	9,500	76.0
Converted into electric energy	3,000	24.0
	12,500	100.0

The thermal efficiency of such plants, as given by different writers, runs as high as 33, 36, 38.5 per cent, and for some plants figures as extravagant as "above 40" are boldly published. Although the present aim has been to present figures for a producer-gas plant that may compare favorably with those of the steam plant of the Interborough Company, an effort has been made to keep well within obtainable efficiencies. Attention is also directed to the fact that the producer-gas plant considered should be large enough to compare favorably with the steam plant. This precludes comparisons with suction plants, which are relatively small, but give higher proportional efficiencies than the larger pressure and down-draft plants, for these require more or less auxiliary apparatus.

Mr. Stott seems ready to accept a thermal efficiency of 24 per cent for the best producer-gas plants, for comparison with 10.3 per cent

efficiency for his steam plant, but a careful study of the problem has led to a more conservative estimate for the producer-gas plant, namely, 21.5 per cent.

The tables just given show the comparative efficiencies reached in plants of the best type, both steam and producer-gas, but these are seldom realized in common practice. The results obtained in the Government plant at St. Louis are probably more nearly representative of the ordinary type of apparatus. These results are as follows:

Relative economies of steam and gas power plants at St. Louis in the conversion of one pound of coal containing 12,500 British thermal units into electricity.

	Steam power.		Gas power.	
	British thermal units.	Per cent.	British thermal units.	Per cent.
Losses in exhaust, friction, etc	11,892	95.14	10,812	86.5
Converted into electric energy	608	4.86	1,688	13.5
	12,500	100.00	12,500	100.0

The following table shows the comparative results obtained at St. Louis from 75 bituminous coals and 6 lignites used in the gas producer and under the steam boiler.

Table showing equivalent pounds of coal as fired per electrical horsepower per hour developed at the switchboard, for both steam and producer-gas plants.

Fuel used.	Locality.	Steam.	Producer gas.
Alabama No. 2	Carbon Hill	4.29	1.71
Colorado No. 1	Lafayette	6.04	2.14
Florida (peat) No. 1	Orlando	.....	3.03
Illinois No. 3	Marion	4.74	1.93
Illinois No. 4	Troy	5.47	2.01
Illinois No. 6	Coffeen	6.28	2.02
Illinois No. 7	Collinsville	5.21	2.41
Illinois No. 8	Paisley	6.26	1.98
Illinois No. 9	Staunton	5.22	2.01
Illinois No. 10	West Frankfort	4.88	1.59
Illinois No. 11	Carterville	4.35	1.37
Illinois No. 13	Burton	4.17	1.74
Illinois No. 14	Springfield	5.27	1.79
Illinois No. 15	Centralia	4.61	1.80
Illinois No. 16	Herrin	4.24	1.81
Illinois No. 18	La Salle	4.53	1.74
Illinois No. 19	Zeigler	4.09	1.47
Indiana No. 1	Mildred	4.95	2.17
Indiana No. 2	Boonville	4.78	1.68
Indiana No. 3	do	4.92	1.97
Indiana No. 5	Hymera	4.74	1.51
Indiana No. 6	do	4.78	1.94
Indiana No. 7	Littles	4.39	1.65
Indiana No. 8	Terre Haute	4.52	1.61
Indiana No. 9	Macksville	4.63	1.84
Indiana No. 11	Dugger	4.37	1.73
Indian Territory No. 1	Henryetta	4.37	1.92
Indian Territory No. 4	Lehigh	4.95	1.57
Iowa No. 2	Marion County	5.82	2.07
Kansas No. 5	West Mineral	4.11	1.57
Kentucky No. 1	Straight Creek	3.72	1.41
Kentucky No. 3	Earlington	4.58	2.05
Kentucky No. 5	Big Black Mountain	3.54	1.39
Kentucky No. 6	Paintsville	3.68	1.33
Kentucky No. 7	Central City	4.36	1.65
Missouri No. 2	Bevier	5.44	1.94

Table showing equivalent pounds of coal as fired per electrical horsepower per hour developed at the switchboard, for both steam and producer-gas plants—Continued.

Fuel used.	Locality.	Steam.	Producer gas.
Montana No. 1	Red Lodge		2.54
North Dakota No. 1	Lehigh	10.09	2.82
North Dakota No. 2	Williston		3.80
North Dakota No. 2	do		2.83
North Dakota No. 3	Wilton	8.46	3.24
Ohio No. 3	Shawnee	4.27	1.51
Ohio No. 4	Bradley	3.98	1.34
Ohio No. 5	Rush Run	3.96	1.26
Ohio No. 6	Neffs	4.00	1.30
Ohio No. 7	Danford	4.16	1.67
Ohio No. 8	Dixie	4.25	1.56
Ohio No. 9	Clarion	3.91	1.43
Pennsylvania No. 4	Greensburg	3.63	1.42
Pennsylvania No. 5	Ellsworth	3.52	1.28
Pennsylvania No. 6	East Millsboro	3.83	1.23
Pennsylvania No. 7	Ligonier	3.88	1.68
Pennsylvania No. 8	Ehrenfeld	3.43	1.28
Pennsylvania No. 10	Bruce	3.55	1.32
Texas No. 1	Crockett		3.34
Texas No. 2	Hoyt		2.58
Virginia No. 1	Crab Orchard	3.66	1.53
Virginia No. 2	do	3.58	1.38
Virginia No. 3	Toms Creek	3.57	1.21
Virginia No. 4	Darby	3.56	1.31
West Virginia No. 1	Kingmont	3.98	1.60
West Virginia No. 4	Bretz	3.71	1.32
West Virginia No. 7	Sun	3.65	1.50
West Virginia No. 8	Ansted	3.83	1.82
West Virginia No. 9	Powellton	3.58	1.43
West Virginia No. 12	Big Sandy	3.59	1.53
West Virginia No. 13	Page	3.45	1.04
West Virginia No. 14	do	3.41	1.10
West Virginia No. 18	Glen Allen (?)	3.43	1.20
West Virginia No. 20	Acme	3.46	1.31
Wyoming No. 2	Cambria	6.64	2.28
Wyoming No. 2	do	5.64	2.28
Wyoming No. 3	Aladdin	5.35	2.04
Brazil No. 1	Porto Alegre	6.43	2.60

Especial attention is called to the fact that several low-grade coals and lignites that have proved of little value or even worthless under the steam boiler have given excellent results in the gas producer.

The ratios of the total fuel per brake-horsepower hour required by the steam plant and producer-gas plant, under full load, not counting stand-by losses, are presented below as derived from 76 coals, 6 lignites, and 1 peat (Florida).

Ratios of fuel used in steam and gas plants.

Average ratio coal as fired per brake-horsepower hour under boiler to coal as fired per brake-horsepower hour in producer..... **2.7**

Maximum ratio coal as fired per brake-horsepower hour under boiler to coal as fired per brake-horsepower hour in producer..... **3.7**

Minimum ratio coal as fired per brake-horsepower hour under boiler to coal as fired per brake-horsepower hour in producer..... **1.8**

Average ratio lignite and subbituminous coal as fired per brake-horsepower hour under boiler to lignite as fired per brake-horsepower hour in producer.. **2.7**

Maximum ratio lignite and subbituminous coal as fired per brake-horsepower hour under boiler to lignite as fired per brake-horsepower hour in producer.. **2.9**

Minimum ratio lignite and subbituminous coal as fired per brake-horsepower hour under boiler to lignite as fired per brake-horsepower hour in producer.. **2.2**

Average ratio peat as fired per brake-horsepower hour under boiler to peat as fired per brake-horsepower hour in producer..... **2.3**

The figures for the producer-gas tests include not only the coal consumed in the gas producer, but also the coal used in the auxiliary boiler for generating the steam necessary for the pressure blast—that is, the figures given include the *total* coal required by the gas-producer plant.

In the above comparisons between the steam and producer-gas plants no consideration has been made of stand-by losses. The result for each plant has been derived from experiments made during continuous operation for a given period. Data on stand-by losses for plants operated during a portion of each 24-hour day are not at present obtainable at the fuel-testing plant. Very few results of experiments relating to this point have been published, and opinions regarding the amount of fuel required for holding fires over night or during idle periods in both boiler and producer plants seem to differ widely. It is probable that the most reliable figures available to-day concerning this matter are those presented by Messrs. Dowson and Larter in their recent book entitled "Producer Gas." The results obtained by these gentlemen from a number of engineers and experimenters, including such well-known experts as Mr. Bryan Donkin, indicate that for plants of about 250 horsepower the stand-by losses amount to about 67 pounds of coal per standing hour for the steam plant and to about 4 pounds per standing hour for the producer-gas plant.

In considering the possible increase in efficiency of the boiler tests with a compound engine, as compared with the simple engine used, the fact should not be overlooked that a corresponding increase in the efficiency of the producer-gas tests may be brought about under corresponding favorable conditions. Not only is the producer passing through a transitional period, but the gas engine must still be regarded in the same light. In the larger sizes the vertical single-acting engine is being replaced by the horizontal double-acting engine. Other changes and improvements are constantly being made, which tend to increase the efficiency of the gas engine as compounding and tripling the expansions have already increased the efficiency of the steam engine.

As has already been stated, the engine used in the tests here reported is of a type that is rapidly becoming obsolete for this size, viz, vertical, three-cylinder, single-acting.

A brief consideration of these points will lead at once to the conclusion that the producer-gas plant and steam plant used in these tests compare very favorably, and that any increase in efficiency in the boiler tests that might result from using a compound engine can be offset by the introduction of a gas engine of more modern type and a producer plant designed to handle the special kinds of fuel used.

It should be noted that many fuels which give poor results under steam boilers have been used with great ease and efficiency in the gas producer, which thus makes it possible to utilize low-grade coals and lignites that have heretofore been regarded as practically useless. Several of the poorest grades of bituminous coals have shown remarkable efficiency in the gas producer, and lignites and peat have been used in it with great readiness, thus opening the way to the introduction of cheap power into large districts that have thus far been commercially unimportant owing to lack of industrial opportunities. Recent experiments with "bone," a refuse product in bituminous coal mining, have given excellent results, showing an efficiency in the product equal to that reached by good steam coal under boilers.

EFFICIENCIES.

It has not been the aim of the testing plant to determine the lowest possible amounts of coal that could produce a given amount of power or to determine the highest possible efficiency of the particular producer plant installed. By an act of Congress, the work of the plant was restricted to the determination of the possibilities of utilizing bituminous coals, lignites, and other fuels for the production of power. In spite of the fact that no series of runs has been made on any one coal for determining the best possible results obtainable, it is nevertheless gratifying to report that official records show that as small an amount of dry coal as 0.95 pound per hour has been burned in the producer per electrical horsepower developed at the switchboard; or 0.80 pound of dry coal per hour has been burned in the producer per brake horsepower per hour, on the basis of an efficiency of 85 per cent for generator and belt.

VIEWS OF MANUFACTURERS OF PRODUCER-GAS PLANTS.

In order to determine as closely as possible the exact status of the producer-gas business, an effort has been made to ascertain the point of view of both the manufacturers and the owners and operators of existing plants. With this object in mind the following question was addressed, about a year ago, to several manufacturers of gas producers:

To what extent is the demand for gas engines and gas producers, and the interest in the same, growing?

The replies were sufficiently significant to warrant their presentation at this time, each reply being separately numbered:

1. We believe there is a waiting and almost unlimited demand for producer power plants, as soon as the manufacturers have something definite to offer and can guarantee quick installation and certain results.

2. The demand for gas engines and gas producers is growing considerably. We have this month closed for an 8,000-horsepower gas-producer plant, and have on our book negotiations pending for over 200,000 horsepower.

3. The demand for gas engines and gas producers is at present apparently only limited by the output, we ourselves having orders way ahead and all the business we

can possibly fill. Were we to go out after business we would immediately swamp the factory. These plants are giving such excellent results in the field that they are bound to replace steam for almost all uses, and in consequence the field may be said to be almost unlimited.

4. The demand for gas producers and the interest manifested in them seems to be growing very rapidly, as indicated by the number of inquiries received at our office and by our agents in different parts of the country.

5. According to inquiries which we are constantly receiving we judge that the interest in the question of gas producers and gas engines is growing considerably, and all indications lead us to believe that the proposition to install gas-power plants will be a very important one in this country before long.

6. Our correspondence indicates a continually growing demand for gas producers for power purposes, especially those adapted for running on soft coals.

7. There has probably never been a mechanical production more widely or thoroughly advertised at such an early period in its history of this country as the suction-producer gas-power equipment. Much of this advertising has aroused curiosity among people, many of whom are not contemplating a purchase. On the other hand, the fuel economy is so remarkable that manufacturers with a reputation for reliable goods and with the fuel guarantees they offer, backed by unquestioned responsibility, are able to sell their product with very little effort.

8. The gas-producer business and the uses to which they have been applied have increased about 50 per cent within the last ten years, and are still growing. We should imagine that the next ten years would show a far greater improvement. We think producer gas is yet in its infancy as to various applications.

9. The demand for gas engines and gas producers is growing in that field where the price of coal is highest, and for that reason any commercial tests in suitable gas producers which will use the fuel of the district will be of value.

10. There is no doubt that the gas engine itself is nowadays in such a state of perfection that its use is bound to become general for power production as soon as the possibility of using bituminous coal to a large extent has been proved.

At the same time the manufacturers were asked:

What are the serious difficulties in the way of more rapid development of gas producers and gas engines as a means of developing power?

A summary of the replies would indicate the difficulties to be about as follows:

1. The fact that the gas engine is not yet so reliable as the steam engine.
2. The lack of engineers who know how to run producer-gas power plants.
3. Inexperienced salesmen—men not familiar with the details of the engines and producers they are handling.
4. The large number of unsuccessful and only partially successful installations made during the experimental period of this development.
5. Lack of proper design and construction of producer-gas engines in the United States.
6. Lack of knowledge and confidence on the part of the public.
7. The fact that the heating of factory buildings must be provided for by a heating plant separate from the power plant.
8. Lack of types of producers which will gasify bituminous coal satisfactorily.
9. Inability to use cheap fuels in the suction gas producer.
10. Lack of complete knowledge as to how successfully the various fuels in different localities can be used in gas systems.
11. Large excess cost of gas-engine–gas-producer power plants over that of steam-power plants.

PRESENT STATUS OF THE GAS ENGINE.

When the manufacturers of producer-gas plants are themselves ready to acknowledge the difficulties outlined above, the situation is most encouraging for the future development of the plants.

Over a year has elapsed since these communications were received, and it is therefore desirable to reexamine the situation briefly but critically to-day, and to consider carefully the 11 difficulties listed above.

1. The fact that the gas engine is not yet so reliable as the steam engine.

There have been good grounds for the feeling that the gas engine was less reliable than the steam engine, but to-day many installations tend to change this impression.

Mr. Paul Windsor, chief engineer of motive power and rolling stock, Boston Elevated Railway Company, says, in an article on the producer-gas power plants installed by his company:

> As a result of my experience with these plants I am absolutely convinced of the economy and reliability of a gas-engine power station.

In order to counteract any lack of confidence in the possibilities of the continuous operation of gas producers and gas engines an endurance test was undertaken at the testing plant at St. Louis, which demonstrated beyond dispute the possibility of operating continuously a producer plant using bituminous coals for power production. The test began March 8 and continued without interruption until April 1, 1905, twenty-four consecutive days.

The average of six analyses of the coal used is as follows:

Analysis of coal used in endurance test.

Moisture	14.68
Volatile matter	30.98
Fixed carbon	42.93
Ash	11.41
	100.00
Sulphur	1.33

12,343 British thermal units per pound of dry coal.

During this entire test calorimetric determinations of the heat value of the gas were made every twenty minutes and volumetric analyses were made every two hours. The average heat value of the gas for the entire run was 156.1 British thermal units per cubic foot, and the average composition of the gas was as follows:

Average composition of gas in endurance test.

Hydrogen disulphide (H_2S)	0.0
Carbon dioxide (CO_2)	9.2
Oxygen (O_2)	0.0
Ethylene (C_2H_4)	0.4
Carbon monoxide (CO)	20.9
Hydrogen (H_2)	15.6
Methane (CH_4)	1.9
Nitrogen (N_2)	52.0
	100.0

During the progress of the test the usual observations were made at intervals of twenty minutes and careful notes were kept of all incidents connected with the operation of the plant. Among the items of interest those relating to the tar extracted during the test are of special significance, as it has often been stated that no plant mechanically separating the tar could run more than five or six days without shutting down. The total tar extracted during this test amounted to 13,455 pounds, or about 143 pounds of tar per ton of coal burned in the producer.

As the plant was laid out for general test purposes the passages which the gas was obliged to traverse were far more tortuous than those it would have traversed in a plant installed for power purposes only. As a result the gas, in passing through a pipe about 3 feet in length, was forced to make three right-angle turns and pass through a water-seal valve, thus traversing a distance of about 20 feet. This construction, necessary only for testing purposes, was unfortunate in connection with this experiment, and, owing to the deposit of tar in the water-seal valve, brought the test to a close at the end of twenty-four days. With this combination of piping removed, even more remarkable endurance records should be made than the surprising twenty-four-day test here recorded.

In order to remove the ashes, which must be taken out at regular intervals, it is usually considered necessary to shut down the entire plant. As such a shut down would be fatal to an endurance test, a special method of taking out the ashes was employed. The ashes were removed about once every forty-eight hours by simply reducing the pressure under which the producer was operated and running the plant on the suction basis during the hour required for removing the ashes. The men worked with entire ease and comfort during this period.

During the entire twenty-four days the engine showed no signs of heating, clogging with tar, or other trouble. It ran steadily at all times and at the end of the test was in perfect condition. The same set of igniters was used throughout the run, and gave absolutely no trouble. An inspection of the engine at the close of the test showed that the cylinders, igniters, and all working parts were in such excellent condition that the engine was not even cleaned nor its mechanism in any way changed before beginning the next test. An inspection of the producer plant at the close of the test also showed that everything about the plant was in excellent condition, and the regular tests went on as usual after the close of the endurance run.

During this test an average of 225.5 brake horsepower was maintained. The coal consumed was 1.40 pounds of dry coal per brake

horsepower per hour. Especial attention is called to the fact that during this test, as well as during all other tests conducted at this plant, no attempt was made to remove the sulphur from the gas before it entered the engine. Considerable controversy has arisen in various parts of the country regarding the influence of sulphur on the cylinders of a gas engine, leading to the introduction of this question into some important lawsuits. The engine used at the testing plant since its establishment has received the full charge of sulphur contained in the gas, and shows absolutely no signs of injury from this source, although some of the coals used have contained as much as 8.1 per cent of sulphur.

2. The lack of engineers who know how to run producer-gas power plants.

It can not be denied that many of the difficulties charged to producer-gas power plants are due entirely to incompetent operators. Some plants have been temporarily put out of commission by the prejudices or the lack of ability and training of the operators or engineers in charge. A few of these failures are due to the impossibility of finding men competent to operate the plants, but many of them have undoubtedly been the result of a short-sighted policy on the part of some manufacturers, who are not willing to give proper and necessary information about the design, construction, and operation of the plants made by them. The possibility of a sale at the time is apparently the only interest they keep in mind, and the future is allowed to take care of itself. In the course of a round of visits recently made to a number of plants my attention was called to several such derelictions.

3. Inexperienced salesmen—men not familiar with the details of the engines and producers they are handling.

The ignorance and short-sighted rapacity of unscrupulous salesmen, who have given absurd guaranties and have made unfortunate installations in certain localities, have seriously injured the reputation of some manufacturers and interfered with further business in the same districts. One salesman, representing a house of national reputation, told me that the suction producer made by his firm (which had then completed only one such producer, still in the factory) was guaranteed to operate perfectly on charcoal, anthracite coal, coke, bituminous coal, lignite, and peat. When I informed him that I was ready to buy out the whole producer business of his firm at once if he would put that guaranty in writing, he became decidedly confused.

One agent "worked" an old gentleman in a small town by convincing him that a producer-gas plant was exactly adapted to the intermittent demands of a small gristmill—a mill which may to-day

run two hours; to-morrow, seven, and then not again for two or three days. The salesman insisted that his producer plant would do everything exactly as desired—that is, it was just the plant for variable demands. As the old gentleman said, "He offered me a gold brick and I bought it. There it stands." The mill is now run by an electric motor supplied with current from the town-lighting plant.

4. The large number of unsuccessful and only partially successful installations made during the experimental period of this development.

Many failures or only partially successful installations are due in part to the willingness of small companies with little financial backing to allow the public to "be the dog" instead of thoroughly testing their plants before putting them out. The need of money, the anxiety to get ahead of competitors, the lack of knowledge, and the incompetence of designers, operators, and salesmen have combined in the past to produce an unfortunate situation, which, however, is rapidly improving.

5. Lack of proper design and construction of producer-gas engines in the United States.

For lack of proper construction many engines have failed utterly to meet the demands made upon them and have been withdrawn. To-day the majority of manufacturers realize that a special engine must be designed for producer-gas work, and that an engine designed for city gas, or gasoline, and then "patched up" to work on producer gas must be a sorry failure.

6. Lack of knowledge and confidence on the part of the public.

Ignorance of the capabilities of producer-gas plants and lack of confidence in them have been largely due to the five difficulties already mentioned and will be remedied as these are remedied.

7. The fact that the heating of factory buildings must be provided for by a heating plant separate from the power plant.

The necessity of heating factories by means of separate plants may be a serious factor in some places. Several companies, however, claim that they have satisfactorily solved this problem. It is by no means impossible of solution, and simple, practical methods of utilizing the heat from the exhaust, or the producer gas directly, will undoubtedly be devised in the near future.

8. Lack of types of producers which will gasify bituminous coal satisfactorily.

There are to-day at least two types of producers which will gasify bituminous coal reasonably well—the pressure and the down-draft plants. I am informed that producer-gas plants aggregating over 200,000 horsepower are now in operation in America on various kinds of fuel, ranging from wood to the best grades of bituminous coal. The work accomplished by the United States Geological Sur-

vey fuel-testing plant certainly establishes beyond doubt the possibilities in this direction.

9. Inability to use cheap fuels in the suction gas producer.

The impossibility of using cheap fuels in the suction plant is a drawback to its proper development. Several companies claim that they have solved this problem, but authorized statements of results are not yet available.

10. Lack of complete knowledge as to how successfully the various fuels in different localities can be used in gas systems.

The special object of investigation[a] made at the Geological Survey's fuel-testing plant for the past three years has been to determine the relative fuel values of coals found in the United States, and it is expected that, as its results become available, this work will supply all necessary information concerning the various kinds of fuel tested.

11. Large excess cost of gas-engine–gas-producer power plants over that of steam-power plants.

Although producer-gas plants have heretofore been more expensive than steam-power plants the cost of gas plants is decreasing, and the statement above is at least open to discussion if not to contradiction, at least as applied to some installments.

Since definite information relating to the cost of producer-gas installations is difficult to obtain, an attempt has been made to procure estimates of cost from all of the leading manufacturers in the United States.

The conclusion reached is that complete producer installation for the larger plants—say from 4,000 to 5,000 horsepower—costs about the same as that of a first-class steam plant of the same size. With smaller installations the balance may be in favor of the steam plant. However, even if the steam plant cost 15 per cent less than the producer-gas plant it should not be forgotten that the increased efficiency in operating the latter will make up the difference in the first cost within a short time—probably in about two years in the average plant. The difference in first cost of plants of over 1,000 horsepower, with coal at $2.75 or more per ton, is usually wiped out within the first year of operation.

In view of the difficulty of determining the exact basis of comparison of the costs of steam and producer-gas plants, I have decided to present the following very complete table, given by Mr. Stott in his paper previously referred to, entitled "Power Plant Economics." Mr. Stott says:

In this table will be found a tabulation of the relative values of the various items necessary in the maintenance and operation of a power plant. The first column covers a plant with compound condensing reciprocating engines without superheat,

[a] For detailed reports see Bull. U. S. Geol. Survey Nos. 261 and 290, Prof. Paper U. S. Geol. Survey No. 48 (3 parts), and other reports on the subject published by the United States Geological Survey.

and is derived from a year's record of actual costs of a large plant operating with a load factor of approximately 50 per cent, load factor in this case being defined as—

$$\frac{\text{Actual output}}{\text{Maximum hour's load} \times 24}.$$

The values in the other columns have in the main been estimated from the first column, but wherever possible actual data derived from various sources, both domestic and foreign, have been used; but in all cases values have been reduced so as to make them directly comparable with the first column and with one another. The values in maintenance and operation of steam turbines are derived from actual costs.

Distribution of maintenance and operation charges per kilowatt-hour.

[Stated in percentages.]

Item.	Reciprocating engines.	Steam turbines.	Reciprocating engines and steam turbines.	Gas-engine plant.	Gas engines and steam turbines.
Maintenance.					
1. Engine room, mechanical	2.57	0.51	1.54	2.57	1.54
2. Boiler room or producer room	4.61	4.30	3.52	1.15	1.95
3. Coal and ash handling apparatus	0.58	0.54	0.44	0.29	0.29
4. Electrical apparatus	1.12	1.12	1.12	1.12	1.12
Operation.					
5. Coal and ash handling labor	2.26	2.11	1.74	1.13	1.13
6. Removal of ashes	1.06	0.94	0.80	0.53	0.53
7. Dock rental	0.74	0.74	0.74	0.74	0.74
8. Boiler-room labor	7.15	6.68	5.46	1.79	3.03
9. Boiler-room, oil, waste, etc	0.17	0.17	0.17	0.17	0.17
10. Coal	61.30	57.30	46.87	26.31	25.77
11. Water	7.14	0.71	5.46	3.57	2.14
12. Engine room, mechanical labor	6.71	1.35	4.03	6.71	4.03
13. Lubrication	1.77	0.35	1.01	1.77	1.06
14. Waste, etc	0.30	0.30	0.30	0.30	0.30
15. Electrical labor	2.52	2.52	2.52	2.52	2.52
Relative cost of maintenance and operation	100.00	79.64	75.72	50.67	46.32
Relative investment in per cent	100.00	82.50	77.00	100.00	91.20

VIEWS OF OWNERS AND OPERATORS OF PRODUCER-GAS PLANTS.

About twenty companies in the United States are to-day manufacturing gas producers for power purposes. At least twelve of these are fully established on a commercial basis and are in position to give proper guaranties when installing plants.

Over 300 gas-producer power plants, ranging in size from 20 to 6,000 horsepower, are now in operation in the United States. One company alone reports twenty-odd installations, averaging over 2,000 horsepower each, and nearly as many more, averaging about the same size, contracted for or now being erected.

The number of installations and the persistent development has already led the National Board of Fire Underwriters to issue special rules and requirements for the "Construction, installation, and use of coal-gas producers (pressure and suction systems)."

Of the total number of installations in the United States it is interesting to note that about two-thirds are suction plants, operating on

anthracite coal, a few using charcoal. Bituminous coal is used in 15 to 20 per cent of the plants installed, but this proportion probably covers 65 to 75 per cent of the aggregate horsepower rating.

During the summer of 1906 it was my privilege to visit several of the producer-gas power plants of the country with the idea of ascertaining from their owners and operators their exact uses, efficiency, and defects. No selection was made of the plants to be visited. The list included producers made by fourteen manufacturers, and the territory visited extended from Maine to central Nebraska.

The deductions made from these visits are:

1. The plants as a whole are giving remarkable satisfaction, considering the very brief period of development that has passed since the introduction of this type of power.

2. The most serious difficulty seems to arise from the lack of competent operators to run the plants rather than from defects or troubles inherent in the plants themselves.

3. Inexperienced salesmen are undoubtedly to blame for serious misrepresentations and misunderstandings.

4. The neglect shown by some manufacturers in respect to their plants after they are installed and paid for has not been far-sighted, and the failure of manufacturers to give the purchasers or operators of plants full information regarding their construction and method of operation has certainly been detrimental to the business.

The situation as a whole at the present time seems to be very favorable for the producer-gas plant, not only as to cost of installation, operation, and maintenance, but also as to reliability. The successful demonstration at the Government fuel-testing plant that bituminous coals, lignites, and peats can be utilized with great economy in these plants should lead to an increase in the use of this form of power within the next few years that may surpass even the most sanguine hopes of the manufacturers.

CENTRALIZATION OF POWER DEVELOPMENT AND DISTRIBUTION.

The rapid increase in the use of electrical power will be greatly accelerated within the next few years by the reduction in cost of power production made possible by the introduction of the gas producer. It would seem ridiculous to predict the immediate doom of the steam locomotive, yet one of the officials of the New York Central Railroad has publicly stated that within ten years, in his opinion, there will be no steam locomotives operating on the New York Central road. Already the New York Central has substituted electric for steam power on its lines from New York City to a point about 40 miles from the Grand Central Station, and it is rumored that before long electric trains will be running on this road from New York to

Buffalo. The Pennsylvania road is to abandon the use of the steam locomotive between Atlantic City and Philadelphia, and the New York, New Haven and Hartford is following the same line of progress by running its trains from Stamford, Conn., to New York City by electric power.

These rapid changes are leading to one end—the centralization of power development and distribution. Now that it is commercially possible to transmit electrical power for distances of 250 or more miles, a central plant could distribute such electric current for a distance of 500 miles—that is, for 250 miles on all sides of the plant—thus covering a circle comprising almost 200,000 square miles—an area nearly four times the size of the State of Illinois. The logical location of such a plant is at or near the mines. With ten or twelve of these great central plants located at the various mining centers, the great railroads of the United States can send their trains speeding from the Atlantic to the Pacific coast; and the passengers, as well as the towns through which the trains pass, will be entirely freed from the usual annoyance of smoke and cinders, and the disastrous fires caused by sparks from locomotives will be a thing of the past.

CONDITION OF THE COAL-BRIQUETTING INDUSTRY IN THE UNITED STATES.

By EDWARD W. PARKER.

GENERAL STATUS OF BRIQUETTING.

Although the briquetting of coals and lignites has been carried on for many years in Europe, and has reached a particularly high state of development in France, Belgium, and Germany, it has made comparatively little progress in the United States. The causes for the backwardness of the United States in this regard are several, and first among them has been the abundant supply of cheap raw fuel with which the manufactured article has to compete. With our millions of acres of coal-producing lands, in which the coal can in most places be cheaply mined, it has appeared in many districts to be more economical to waste the slack or culm, which constitutes a considerable percentage of the product, than to attempt to save it at the additional expense required for briquetting. For this reason large tracts in the anthracite region of Pennsylvania are covered by unsightly culm banks which encumber the ground and mar the view, and in some of the bituminous districts huge piles of unmarketable slack are allowed to burn in order to get rid of them. When the coal is of coking quality, or when the slack can be used for steaming purposes, these losses are not sustained, but many thousands of tons of material that might be converted into usable fuel have been wasted every year simply because of the increased expense involved in its preparation.

The development of the briquetting industry has also been retarded by attempts to exploit patented or secret processes, for which all kinds of extravagant claims have been made, but which have almost invariably proved expensive and unprofitable, and the investment of capital in enterprises of this character has been accordingly discouraged. The Patent Office records teem with patents issued on all sorts of inventions relating to binders, many of which are as fanciful as the idea of perpetual motion.

Another reason for the failure to build up a briquetting industry in the anthracite region of Pennsylvania, where the best opportunity for its development is offered, has been the opposition shown by some of

the operators to the introduction of a manufactured domestic fuel which would come in competition with the prepared sizes of anthracite. And such an opposition is natural. The competition of bituminous coal has almost entirely shut out anthracite as a steam fuel. Coke for iron making has almost entirely supplanted anthracite, and the use for domestic purposes of coke and gas made from bituminous coal is growing. Owing to the greater depths to which the mining of anthracite is being carried, the thinner and less favorably located beds which are being worked, and the increasing cost of labor, the mining and preparing of anthracite is becoming more expensive on one hand, while competition is becoming keener on the other. A certain rate of production must be kept up for the protection of the properties themselves, and, when all the conditions are considered, the unfavorable attitude on the part of the operators toward further competition is at least realizable.

Still another reason which has been assigned, rightly or wrongly, for our halting progress in fuel briquetting has been the lack of assurance of a regular supply of coal-tar pitch at reasonably low prices. For out of the many attempts that have marked the incubating period of briquetting development—some of them costly—has grown the knowledge that coal-tar pitch must be relied on to supply, in the Eastern States at least, all or the greater part of the binding material. In California, Arizona, and other parts of the Far West asphaltic pitch, the residual product from the refining of the heavy asphalt-base petroleums of that region, has been and is now successfully used in recently constructed briquetting plants. But in the East coal-tar pitch is the base of the economically successful cementing material—a fact that has been fully demonstrated by the extended investigations carried on at the United States Geological Survey's fuel-testing plant at St. Louis.[a] These investigations included experiments with all kinds of organic and inorganic binders, embracing, besides coal-tar pitch, such materials as rosin, sugar-house refuse, molasses, acid sludge, quicklime, and various mixtures. The results show that either coal-tar or asphaltic pitch are the only really successful binders. Any materials used with them must possess above all others the essential virtue of cheapness.

But while it is claimed on one side that the briquetting industry has been held back by the lack of assurance of a steady supply of coal-tar pitch, it also happens that one of the reasons assigned for the comparatively slow development of the by-product coking ovens in the United States in the last few years is the lack of a profitable demand for coal tar, an important by-product of retort coke ovens. It is well known that the demand for creosoting oils to be used by rail-

[a] Bulls. U. S. Geol. Survey Nos. 261 and 290; Prof. Paper U. S. Geol. Survey No. 48.

road companies for preserving ties, bridge timbers, etc., is far beyond the present domestic production of that coal-tar product, and the statistics compiled by the Bureau of Statistics of the Department of Commerce and Labor show that our imports of the chemical products of coal tar amount to over $10,000,000 in value yearly. To the ordinary observer it would appear that the conditions here presented afford an opportunity for the recognition of a community of interests which may be profitable to the manufacturers and beneficial to the general public. The constantly increasing expense involved in mining and preparing anthracite coal is slowly but surely making that commodity more and more a luxury, and manufactured fuel which will take the place of anthracite for domestic use, particularly among consumers of moderate means, appears to be needed. This is especially true in the northeastern section of the United States.

Two of the briquetting plants, which have been recently constructed, and which are discussed in detail in the following pages, indicate somewhat a "getting together" of the coal-tar producing and the briquetting interests. These are the plants of the United Gas Improvement Company, at Point Breeze, Philadelphia, and of the Semet-Solvay Company, at Del Ray, Mich. Both companies are producers of coal tar, and the plants have been constructed for the purpose of briquetting mixtures of anthracite culm and coke breeze.

It appears now, moreover, that the period of failure and discouragement in the manufacture and use of briquetted fuel has passed and that the industry will be placed on a substantial footing.

BRIQUETTING PLANTS IN THE UNITED STATES.

GENERAL STATEMENT.

The first successful plant in the United States of which the writer has any definite knowledge was built at Stockton, Cal., a few years ago by the San Francisco and San Joaquin Coal Company. This plant, unfortunately, was entirely destroyed by fire in 1905, and the plans for its reconstruction at San Francisco were interrupted by the earthquake and fire which destroyed a large portion of that city in April, 1906.

During the last two years a number of briquetting plants have been built and as complete descriptions of them as it has been possible to obtain are given in the subsequent pages. Some of them have been put in operation since January 1, 1907.

The following list, compiled from newspapers and other sources, shows the name and location of companies which have been organized for the purpose of carrying on the briquetting business, or which

have constructed plants to operate in connection with an already established industry:

Arizona Copper Company, Clifton, Ariz. In operation. (See pp. 477–479.)

Ajax Fuel Company, San Francisco, Cal. Operated small plant in 1905; destroyed by earthquake and fire in April, 1906.

Pittsburg Coal Mining Company, San Francisco, Cal. (See pp. 475–477.)

Eureka Briquette Company, Oakland, Cal. Organized, according to press bulletins, with capital of $75,000. Letters addressed to the company were returned unclaimed.

San Francisco and San Joaquin Coal Company, San Francisco, Cal. (See pp. 472–473.)

United States Briquetting Company, San Francisco, Cal. Organized for briquetting mixture of peat and California crude oil. Original plant destroyed by earthquake. Erecting new plant at Stege, Cal. (See p. 477.)

Western Fuel Company, Oakland, Cal. Constructed plant in 1905. (See pp. 473–475.)

American Coal Briquette Company, Washington, D. C. Impossible to locate.

Orlando Water and Light Company, Orlando, Fla. (See p. 481.)

Illinois Coalette Fuel and Mining Company, Alton, Ill. Reported as having organized with capitalization of $1,000,000. No replies received from inquiries.

National Compressed Fuel Company, Chicago, Ill. Organized in 1904 for exploiting the Hoffman patent binder exhibited at the St. Louis exposition. Letters addressed to the company have been returned unclaimed.

Anderson Artificial Coal Company, Anderson, Ind. Incorporated, according to press reports, in 1905; capital stock, $50,000. No replies received to letters.

Globe Coal Manufacturing Company, South Bend, Ind. Incorporated in 1905, but a plant has never been erected.

United States Heyde-Brand Coal Company, Berwick, Me. Letters returned unclaimed.

Eastern Coaleo Manufacturing Company, Baltimore, Md. Organized by L. G. McPherson, T. K. Stewart, and others, but no progress made.

Boston Coal Briquetting Company, Boston, Mass. Letters returned unclaimed.

Semet-Solvay Company, Del Ray, Mich. (See p. 479.)

Gen. Alexander Hughes, Minneapolis, Minn. Carried on some experiments looking toward the briquetting of North Dakota lignite, but has not established any plant.

International Coal Briquette Company, Minneapolis, Minn. Letters returned unclaimed.

Mankato Peat Fuel Company, Mankato, Minn. No replies to letters.

Valentine Coal Binder and Briquette Company, St. Paul, Minn. Letters returned unclaimed.

Coaleo Fuel Manufacturing Company, St. Louis, Mo. No replies to inquiries.

Renfrow Briquette Machine Company, St. Louis, Mo. (See pp. 481–484.)

United States Artificial Coal Company, St. Louis, Mo. Letters returned unclaimed.

Compressed Coal Company, Camden, N. J. Unable to find.

The Briquetting Company, Jersey City, N. J. Letters returned unclaimed.

McGinnis Coal Briquette Company, Jersey City, N. J. Letters returned unclaimed.

Monon Development Company, Jersey City, N. J. Letters returned unclaimed.

New Jersey Briquetting Company, Jersey City, N. J. (See p. 465.)

Sanitation Coal Company, Jersey City, N. J. Letters returned unclaimed.

Peat Fuel Company of New Jersey, Lincoln Park, N. J. No replies to inquiries.

American Fuel Corporation, Newark, N. J. No replies to inquiries.

American Peat Fuel Company, Passaic, N. J. No replies to inquiries.

E. B. Arnold, New York City. (See pp. 468–470.)

The Briquetting Company, New York City. Address given as 52 Broadway. Not found.

Economy Smokeless Coal Company, New York City. Letters returned unclaimed.

D. Grieme Coal Company, New York City. No replies to letters.

International Briquetting Company, New York City. Organized in 1905, but nothing accomplished.

Manhattan Coal Briquette Company, New York City. Letters returned unclaimed.

National Fuel Briquette Company, New York City and Brooklyn, N. Y. (See pp. 477–478.)

New Jersey Briquetting Company, Brooklyn, N. Y. (See pp. 464–467.)

New York Compressed Fuel Company, New York City. Letters returned unclaimed.

North American Coal Briquette Company, New York City. (See p. 478.)

Peat Koal Company, New York City. No replies to inquiries.

Peerless Fuel Company, New York City. Letters returned unclaimed.

Scranton Anthracite Briquette Company, New York City. (See pp. 470–471.)

Standard Briquette Company, New York City. No replies to inquiries.

United States Briquette Company, New York City. Letters returned unclaimed.

Zwoyer Fuel Company, New York City. (See p. 465.)

Briquette Coal Company, Stapleton, N. Y. (See p. 477.)

Koala Fuel Manufacturing Company, Washburn, N. Dak. Letters returned unclaimed.

Hon. W. D. Washburn, Wilton, N. Dak. (See p. 480.)

Composition Fuel Company, Johnstown, Pa. No replies to inquiries.

United Gas Improvement Company, Philadelphia, Pa. (See pp. 471–472.)

R. B. Metcalf, Providence, R. I. Operated a briquetting plant at Portsmouth about ten years ago. Coal found to be unsuitable for briquetting.

International Compress Coal Company, Houston, Tex. (See p. 480.)

North Fort Worth Patent Fuel Company, Fort Worth, Tex. No replies to inquiries.

Eureka Briquette Company, Rockdale, Tex. (See p. 480.)

American Lignite Briquette Company, San Antonio, Tex. (See p. 480.)

International Fuel Company, Rutland, Vt. Organized by the late Henry R. Dorr to manufacture briquettes from anthracite culm. Nothing done since the death of Mr. Dorr in 1906.

Bellingham Briquetting Company, Bellingham, Wash. Organized with a capital of $75,000; nothing done in the way of construction.

Southern Pacific Coal Company, Carbonado, Wash. No replies to inquiries.

Pacific Coke and Coal Briquetting Company, Spokane, Wash. Letters returned unclaimed.

NEW YORK, N. Y.

New Jersey Briquetting Company.—During 1904 and 1905 the New Jersey Briquetting Company, of New York, constructed at the foot of Washington street, Brooklyn, a plant for exploiting the Zwoyer Fuel Company's briquetting process. This plant was intended to be operated in connection with a coal yard on Adams street, but during the construction of the piers and anchorages for the new Manhattan Bridge the company was prohibited from operating the tramway from the coal yard to the plant. This interfered with the operations of the plant, and as extensive storage capacity, either for raw material or for the product, had not been provided for at the site, the work done has been accomplished under much disadvantage. The prohibition put on the tramway and the lack of dock facilities for loading and unloading material has crippled the plant to such an

extent that what was supposed to be an excellent location has turned out to be an unfortunate one, and the present methods of receiving and handling the material make the operations so expensive that the briquettes can not successfully compete with raw fuel. As a result of these unfortunate conditions it is proposed to remove the plant to a site better adapted for receiving, storing, and shipping the material. The officials of both the New Jersey Briquetting Company and the Zwoyer Fuel Company are entirely satisfied with the experimental results.

A description of the plant in Brooklyn was published in the Iron Age, from which the following notes have been in part abstracted, additional matter having been furnished by Virgil H. Hewes, treasurer of the Zwoyer Fuel Company.

Prior to the construction of the plant in Brooklyn the Zwoyer Fuel Company had built a small plant in Jersey City, N. J., which was of sufficient capacity for experimental work, but not large enough to be operated as a commercial undertaking, and was abandoned.

It may be stated here that, after a considerable expenditure of time and money in experimenting with different kinds of binders, coal-tar pitch was finally selected as the material best suited to the work, a decision which has been generally reached in the Eastern States, asphaltic pitch having been adopted in the Far West, where that article is cheaply obtained. During the progress of the experimental work about 200 tons of briquettes were made with a binder composed of 6¼ per cent of rosin and oil, 1½ per cent of flour and water, and 6 to 10 per cent of bituminous coal, the body of the briquette being anthracite dust. About 900 tons were made with 5 to 7 per cent of rosin and oil and 10 per cent of bituminous coal, 400 tons were made with 5 to 7 per cent of wood pitch and 10 per cent of bituminous coal, and 1,500 tons were made with 6 to 7 per cent of coal-tar pitch alone. In applying the binder during the last three experiments an atomizer was used.

The plant in Brooklyn has a capacity of 10 tons an hour and was built for the purposes of demonstration. During the winter and spring of 1905-6 about 3,000 tons of anthracite briquettes were made and sold. The price received was $5 per ton of 2,000 pounds at the plant, $5.50 per ton delivered, and $6.60 per ton in bags of 100 pounds each. These prices were 50 cents below the prices of the domestic sizes of anthracite.

The building is nearly triangular in outline. The anthracite dust is received on Washington street at the end of a screw conveyor, which carries it to the foot of an elevator, where it is lifted to the top of the plant and spouted to a screen located over the dust bin. The coarser material is spouted either to the boiler room or to an oversize bin in the rear of the dust bin and then fed into a crusher, crushed

and passed to the foot of the dust elevator, where it is again carried to the screen. The dust is drawn from the dust bin by a conveyor, driven from a variable-speed countershaft, and is fed to the 16 by 36 inch roll crusher. It then passes to an elevator and is carried to the mixers. After passing through six mixers it is carried to the second floor, where it falls into the press hopper.

From the press the briquettes are carried by a belt conveyor to the baking oven (when smokeless briquettes are wanted) and are then elevated to and distributed upon the cooling table, which is located on the second floor. After cooling, the briquettes are run into chutes and loaded into wagons for delivering, or are stored. In New York the briquettes sell readily when not baked.

On one side of the dust bin there is a bin from which soft coal is fed into a 19 by 4 inch roll crusher and passed to the same elevator that carries the dust to the mixers. Development has shown that it is not necessary to use soft coal with anthracite dust. However, this bin is used when experimental runs are made requiring the mixing of different materials with the dust.

The binder used is coal-tar pitch, which is received in barrels on the Plymouth street side of the building. It is hoisted to the second floor by means of a barrel hoist; the staves are then removed and the pitch is thrown into the binder melting tank (a tank holding about 15 tons of pitch) and pumped by means of a rotary pump into the storage or hot binder tank, where it is kept heated.

The number of units necessary in a mixer depends on the material to be briquetted and the condition in which it is received. At this plant six mixers are used, which have proved well adapted to the handling of coal (hard and soft, wet or dry), coke breeze, and even iron concentrates.

The dust enters mixer No. 1, and is carried through mixers Nos. 1 to 6, and then by conveyor to the press. In passing through mixers Nos. 1 and 2 the dust is heated by furnaces to drive off all the moisture. The coal-tar pitch, which has been previously heated, is pumped from the storage tank by a small rotary pump driven from a variable-speed countershaft, which regulates the percentage of pitch used. The pitch is atomized by means of a steam jet and delivered to mixer No. 3.

The above apparatus and process are patented.

A press of the roll type is used, the rolls being built up of disks which are milled to form the pockets and then assembled and bolted together on the shaft. This method of constructing the rolls, as well as the design of the briquettes, is patented. Briquettes are made in two sizes—$1\frac{7}{8}$ by $1\frac{7}{8}$ by $1\frac{1}{4}$ inches and $2\frac{1}{8}$ by $2\frac{1}{8}$ by $1\frac{3}{8}$ inches. The briquettes are square "pillow" or "pin-cushion" shape. The smaller ones weigh 2 ounces and the larger 3.3 ounces.

The cooling table consists of three endless belts composed of steel plates carried at their ends by sprocket chains. The belts are placed one over the other and carry the briquettes back and forth six times over a distance of 84 feet, making a total travel of 504 feet. The briquettes are then run into bins or loaded into wagons.

Staten Island plant.—The Briquette Coal Company, J. P. Egbert, manager, No. 2 Stone street, New York City, has just completed the construction of a briquetting plant at Stapleton, on Staten Island. This plant is constructed for the purpose of using anthracite dust as delivered at the plant, with coal-tar pitch as the basis of the binding material. The plant does not possess any novelties in its design except that there are two presses of radically different types. One of these is of German manufacture, having been built at the works of Schuchtermann & Kremer, of Dortmund. This press is of the plunger type and in the manner of feed, compression, and ejection is similar to the Johnson (English) machine used at the Geological Survey testing plant at St. Louis, except that the disk containing the compressing molds is set and revolves horizontally instead of vertically. The briquette is a parallelopiped in shape, with the end edges rounded. The dimensions are 4¾ by 2¼ by 2½ inches and the briquettes weigh about 1.5 pounds. They have a specific gravity of about 1.24.

The second press is of what is generally classed as the Belgian type, similar to the one described as the "American" machine used at the Geological Survey testing plant. This particular machine was made at the works of H. Stevens, at Charleroi, Belgium. The product is of the eggette pattern, which is more desirable for domestic use than the larger briquette. The eggettes weigh about 5 ounces and have a specific gravity of 1.37. The manager of the company, Mr. Egbert, extended to the writer every courtesy possible. The total capacity of this plant, with both presses in operation, is 120 tons of briquettes per day of ten hours. The German machine will turn out 4½ tons and the French machine 7½ tons per hour.

South Brooklyn plant.—Another plant, which has just been completed as this report is written, is that of the National Fuel Briquette Machinery Company of New York City. This plant is located at the foot of Court and Smith streets, Brooklyn, close to the Gowanus Canal, by which the materials to be used can be brought in barges and discharged at a minimum of expense. While intended to be operated on a commercial basis, it may be considered rather as a demonstrating plant. It is planned to use anthracite dust, with coal-tar pitch as a binder. The press is of the Belgian type, producing eggettes or "boulets" somewhat smaller than an ordinary hen's egg, and made exclusively for domestic use. The machinery used in this plant was patented in this country (United States patent No. 799149, September 12, 1905) by Robert Devillers, with

whom the writer visited the plant and to whom acknowledgments are made for courtesies extended. The eggettes here produced are much smaller than those ordinarily made, weighing only about 1.5 ounces each. They have a specific gravity of 1.3.

North American Coal Briquette Company.—This company, whose office is at 177 Broadway, New York City, has been incorporated for the purpose of exploiting the Forst briquetting process. The main feature of this process consists in the material to be used as a binder, part of which is kept secret, but which consists principally of coal-tar pitch. The merit claimed for the secret ingredients of the binder is that they permit a great economy in the quantity of binder used for the manufacture of superior briquettes. The company has negotiated for the purchase of a Duprey (French) machine, and has sent 10 tons of anthracite coal and 1 ton of binder to Paris for the purpose of demonstrating the claims made for this process.

The Mashek briquetting process.—The briquetting press designed by G. J. Mashek (now with the Traylor Engineering Company, New York City) was described in detail by him in the Iron Age of April 19, 1906. It was designed for the purpose of overcoming the objections to the use of briquetting machinery which had developed principally through the failure of certain foreign-made machines to meet the requirements of the American trade. When Mr. Mashek started on the development of his plans, in 1903, the general type of machine in use in Europe was that which made large, rectangular-sided briquettes weighing from 7 to 20 pounds each, and these proved unsuitable to American use. In designing his press Mr Mashek adopted the Belgian idea of molds contained in the periph eries of two tangential wheels, but, instead of the eggette pattern, developed one which minimizes the blank spaces between the molds and produces a briquette of pillow or pincushion shape.

The Traylor Engineering Company has recently built for E. B. Arnold a Mashek press, which has been installed at the foot of West Forty-seventh street, New York City. The building was designed and erected for, and originally equipped with, a different type of machinery, but the briquettes made proved to be of a shape and character unsuited to the trade, and the cost of manufacture was also too high to enable the briquettes to compete with natural coal. When it was decided to substitute a Mashek press for the old one, it was also deemed advisable to use the same building, which is a substantial one, and also as far as possible the old machinery (such as elevators, shafting, power plant, etc.), which was practically new and in good order, but which did not permit the most desirable arrangement.

The new press installed has a capacity of about 14 tons of 2-ounce briquettes per hour, but on account of the inconvenience resulting

from the use of so much of the old equipment it is impossible to handle sufficient material to keep the machinery running at its full capacity and it is now operated at the rate of about 10 tons per hour. The cost of labor, fixed charges, and other expense being the same, the cost of production is slightly higher per ton of briquettes than it would be if the plant were operated up to its maximum capacity. The size of the briquettes has been determined by putting them on the market and selling them for domestic purposes, starting with 1-ounce briquettes and running up to 3 ounces. It was found that the majority of users preferred a 2-ounce size, which corresponds with the "stove" size of anthracite. The weight, of course, will vary with the nature of the dust from which the briquette is made, and it has been found that in using coke breeze a 2½-ounce briquette is most desirable, and about a 3-ounce if made of soft coal and lignite. The press is so designed that a change of the mold shells can be made in about two hours.

The anthracite dust is elevated to the dust bin, from which it is drawn by a feed conveyor so arranged that the feed is constant and can be regulated as desired. This conveyor discharges into a chain elevator, which in turn discharges into a battery of five 18-inch rotary driers and heaters. These are superimposed one above another and all bricked in. The material is conveyed through these driers by means of screw mixers until it passes into the elevator.

On the side of these driers is constructed a furnace, the products of combustion from which are distributed into the driers through openings into the different units, so that no unit gets heat sufficient to either char the dust or burn out the ironwork of the paddle conveyor. An exhaust fan draws off the products of combustion and the moisture. The temperature of the discharge gases and moisture from the drier rarely exceeds 212° F. After the material passes out of the drier into the elevator it is raised and dropped into a 36-inch Williams pulverizer, which crushes the larger pieces so that everything passes through about a 12-mesh screen. From the pulverizer the material is again elevated to another series of mixers and coolers similar in construction to the driers. At this point the anthracite dust has a temperature of about 300° F. The coal-tar pitch is here introduced by means of a pitch pump so arranged that it will deliver a definite quantity of pitch, as desired. Alongside of the last battery of mixers is a small furnace which heats the two upper mixers, maintaining an even temperature in the mixture and not allowing it to stiffen or set. From the last mixer the material drops to an elevator that takes it up to the second floor and discharges it onto an 18-inch belt conveyor, which delivers the material into the hopper of the press. The press is run continually, discharging the briquettes into a perforated pan conveyor, which conveys them to the briquette bin.

While in this conveyor the briquettes are subjected to a heavy spray of water in order to cool and clean them.

The coal-tar pitch used in this plant is of the ordinary roofing hardness. It is delivered by lighter on the adjacent dock and carted to the pitch-melting house, where it is melted in a tank, 6 feet wide, 12 feet long, and 8 feet deep. This tank will hold about 22 tons of pitch, which requires approximately twenty hours to melt. After the pitch is melted and brought up to the proper temperature for use, it is drawn off by means of a large pitch pump into the "prepared-pitch tank,".from which it is pumped into the mixers.

This plant requires about 125 horsepower to turn out 10 tons per hour. It has been in operation about two months and is said to be giving excellent results. The product is used almost entirely for domestic purposes and commands the same price as the best grade of prepared anthracite coal in the New York market. A large portion of the output is put up in paper bags and handled by grocers and small coal dealers the same as charcoal or crushed coke. The bag trade caters to the poor people who do not buy in large quantities and is a considerably cleaner method of distributing the product than that formerly used.

The briquettes are handled in the same way as ordinary coal, and experience in this and other plants has shown that abrasion or breakage averages about 3 per cent, which is slightly less than that with ordinary prepared coal.

PENNSYLVANIA.

It might be supposed that the briquetting industry would have its greatest development in or near the anthracite region of Pennsylvania, where a plentiful supply of raw material is available in the great culm banks created through many years of mining and in the still large amount of fine coal produced at the breakers for which no profitable market has yet been found. Up to the present time, however, there are but two briquetting plants in operation in the State, and one of these is located at Point Breeze, in the city of Philadelphia. The other is located at Dickson, a few miles from Scranton. Both were put into operation in 1906. The plant at Dickson is in the immediate vicinity of the mine of that name operated by the Delaware, Lackawanna and Western Railroad, and uses the fine coal or screenings, below marketable sizes, that come from the washery operated in connection with the mine. The owner of this plant, the Scranton Anthracite Briquette Company, withholds information relative to the details of its operations. The writer has been told, however, by one of the officials of the company, that the base of the binding material used is coal-tar pitch, and that the plant is producing at present (April, 1907) from 300 to 325 long tons of briquettes per day. It is

the intention to double this output by running the plant night and day. The briquettes are of the oval or eggette shape, the press being of the Belgian type and similar to the American machine used at the testing plant of the United States Geological Survey at St. Louis during the exposition period.[a] The entire product is taken by the Delaware, Lackawanna and Western Railroad, for use principally on its locomotives.

The plant at Point Breeze is owned and operated by the United Gas Improvement Company, and was constructed for the purpose of utilizing the coke breeze produced at the gas houses of the company. As at the Dickson plant, the product is not placed on the market, but is used by the company in its retorts for the manufacture of water gas. The writer is indebted to W. H. Gartley, engineer of works, of the United Gas Improvement Company, for the following detailed description of the plant.

It has been found advantageous to use a mixture of anthracite culm and coke breeze, with 5 to 7 per cent of coal-tar pitch as a binder. The proportions of culm and coke used are variable, according to the quantity of material on hand. At the time the writer visited the plant (November, 1906) three parts of culm to two parts of coke were being used. The press is of the Belgian type, producing eggettes about the size of a goose egg. The rated capacity of the plant is 10 tons of eggettes per hour. It has been in operation regularly, producing 90 tons per nine-hour day, except when it has been shut down for repairs and changes.

The breeze or screenings from the coke screen fall into a pocket or hopper, into which is also dumped the culm. The contents are raised by an elevator into a storage tank, discharging through the funnel-shaped bottom onto an automatic feed table, by which a measured stream of the material is continuously poured, part into the crusher and part directly into the hopper below the crusher. The material is then elevated and discharged into the drier. The dried material, together with the dust from the dust chamber of the drier, is elevated and discharged through a shaking screen into a storage tank located above the mixer. All material not fine enough to pass through the screen is returned to the crusher. The dried material is discharged through the funnel-shaped bottom onto an automatic feed table, by which a measured stream is continuously poured into the mixer. Into the feed end of the mixer is also poured a continuous stream of liquid pitch through a positive measuring faucet driven from the driving mechanism of the mixer through a variable speed device. The pitch is brought into the building as broken from the pitch bays of the tar distillery, fed into a pitch cracker, elevated and

[a] Bull. U. S. Geol. Survey No. 261, and Prof. Paper No. 48, 1906.

discharged into large steam-heated pitch storage tanks, where it is melted. From these tanks the melted pitch is drawn, as required, into a smaller steam-heated tank, to which the faucet previously mentioned is attached.

The warm, dry, and continuously measured crushed breeze and culm, together with the melted and continuously measured pitch, are thoroughly mixed and kneaded in the steam-jacketed mixer. The mixed mass is discharged from the mixer, divided into two streams, and carried by two mixing conveyors, allowing time for cooling and setting, into the feed pans of the two presses, purchased in France. The presses form the eggettes and discharge them onto the shaking screens below, which screen out the waste and fines. They are then discharged onto a woven-wire belt conveyor, on which they have time to cool and set, and conveyed either to the cars or to the hoppers from which the buggies for the generator house are filled.

The waste and fines from the shaking screens under the presses are conveyed by conveyors to a hopper at the discharge of the drier.

Screenings from the eggettes taken from the storage piles are returned by an elevator to the discharge of the mixer and assist in the cooling of the heated mixture.

CALIFORNIA.

The manufacture of briquettes has shown more actual progress in California than in any other State of the Union. This has been brought about through efforts to improve the fuel quality of the rather low-grade California subbituminous coals, and has been encouraged by the high prices of the better grades of bituminous coal or anthracite brought into the State from Washington, the Rocky Mountains, and the Eastern States, or imported from British Columbia, England, Australia, and Japan. It has also been encouraged by the abundance of cheap asphaltic pitch, which can be obtained from California petroleum and which not only serves excellently as a binder, but adds to the calorific value of the briquetted fuel.

The first plant to be put into successful operation in California was one built at Stockton by the San Francisco and San Joaquin Coal Company. The plant was completed in 1901, and when running at full capacity could produce 125 tons of briquettes per day. The fuel used was subbituminous coal from the Tesla mine, in Alameda County. The plant was, unfortunately, destroyed by fire in 1905 and has not been rebuilt. It is stated that the plans of the company were to rebuild the plant at San Francisco, but these were upset by the earthquake and fire which destroyed a large part of that city in April, 1906. A complete description of the Stockton plant, by the designer of the presses, Robert Schorr, of San Francisco, was pub-

lished in the Engineering and Mining Journal August 18, 1904. The briquettes produced at this plant were round, convex lenses or "boulets," which weighed from 6 to 8 ounces.

The Western Fuel Company, of Oakland, completed early in 1905 a briquetting plant, also designed by Mr. Schorr.[a] In mechanical construction this plant differs materially from the one destroyed by fire at Stockton. The shape of the briquettes is cubical instead of "boulet.". The advantage claimed for the cubical shape is that the briquettes ignite more readily, though it is admitted that there is more waste in handling.

The capacity of this plant is 480 briquettes per minute, or 8½ tons per hour. The fuel used is coal-yard screenings from lignites, anthracite, and subbituminous coals, with about 7½ per cent of asphaltic pitch. This pitch is obtained by the distillation of California crude petroleum. The temperature of the still for the production of pitch of the proper grade is about 600° F. Some difficulty has been experienced in obtaining suitable pitch on account of the tendency of the refineries to "rush the stills," their aim being the production of refined oils rather than pitch. An excellent asphaltic pitch is obtained by keeping the stills at a temperature of 500° F. and using a vacuum to force the distillation. Grade "D," the quality best adapted for the purpose, is fairly hard up to 60° F., but begins to soften above that temperature. It becomes liquid at 250° F., and has a specific gravity of 1.05 to 1.1.

Before the earthquake the Western Fuel Company paid $10.50 per ton for the ordinary pitch "D" delivered at its plant, and a properly and carefully prepared pitch was worth from $12 to $13. Owing to the enormous building activity in San Francisco since the earthquake the demand for asphaltum for roofing materials has increased by leaps and bounds. Consequently there is a great scarcity and the price per ton ranges now from $14 to $20. This scarcity necessitated many shut downs of the plant at Oakland, and for that reason the company is negotiating for the importation of coal-tar pitch from the East and from Europe. As three new refineries are contemplated, conditions may gradually return to their normal state.

All of the coal purchased and used by the Western Fuel Company is brought in ships and is unloaded by electric hoists into receiving bins. When drawn from the storage bins it is screened, all material that passes through the perforations dropping into auxiliary bins from which it is fed into a Williams crusher. The disintegrated coal from the crusher is elevated into the iron hopper of an automatic feeder that feeds into the coal heater. The heated coal enters the mixer, where it meets the binder. The mixer, the binder distribution, and the tempering of the mixture embody some novel features.

[a] See Eng. and Min. Jour., September 2, 1905.

The prepared material is conveyed into the feed hopper of a Schorr press, style "A," which is belted for 6 revolutions per minute. At that speed 480 briquettes of 9½ ounces in weight are discharged per minute, or more than 17,000 pounds per hour. The briquettes are rectangular in shape, with rounded corners, and uniform in size, 2¾ by 2½ by 1¾ inches, and are branded with a "W." They have a specific gravity of 1.22.

All wearing parts of the press are lined with phosphor bronze, and are thoroughly lubricated under an air pressure of 40 pounds to the square inch. Oil is also atomized and sprayed into the molds and upon the plungers.

The briquettes drop upon a short conveyer that delivers them to another one located outside the building. At this point they are sacked for the local market or taken to the top of the storage bunkers, where they are discharged into cars or distributed into the bunker compartments. The average output is 64 long tons per shift of eight hours. Four men are employed, one of them getting $4, one $2, one $3, and one $2.75 per day, which makes about 20 cents per ton of briquettes. By running twenty-four hours a day over 200 tons could be made, which would reduce the labor item to about 14½ cents per ton. This can be further cut down by speeding the press up to 7 revolutions per minute. This would produce 560 briquettes per minute, or 20,000 pounds of 9½-ounce briquettes per hour. With a forced feed attachment a further increase in speed may be possible.

Since the foregoing was written wages have been increased considerably, most of the men getting $3.50 per shift, working through the lunch hour.

The present pressure arrangement was tested up to 48,000 pounds, exerted on two 2½ by 2¾ inch surfaces, making over 3,700 pounds per square inch. The adjustment is placed to give about 2,900 pounds, which is ample and makes a better burning briquette than when a greater pressure is used. The press is figured for a maximum pressure of 6,000 pounds.

The following description of the briquetting press is taken in the main from an article by Mr. Schorr:[a]

Two soleplates with heavy bearings are arranged to carry a stationary steel shaft, on which a large spur wheel is revolving, driven by means of gearing, countershaft, and friction-clutch pulley. The spur-wheel rim is made integral with a mold ring, which has a series of holes and sliding plungers (pistons) therein. The pistons are under the continuous control of cams, which are supported by heavy shields. The pistons are released from the cam way only when the final pressure is applied, and this is done by a large wheel with steel tire, pivoted in two levers. This wheel is pressed against the piston heads by

[a] See Eng. and Min. Jour., October 7, 1905.

means of an adjustable spring which permits a perfect regulation of pressure up to 4,000 pounds per square inch. After leaving the pressure wheel—that is, after the briquette is made—the plungers are gradually forced forward to eject the briquettes, which drop upon a vibrating discharge chute. The pistons are then gradually withdrawn and in passing the feed box the cavities become filled with the mixture of coal and pitch. At the end of this feed box all surplus material is scraped off by a steel plate. After passing the scraper plate the pistons are gradually forced in, pressing the material against the resistance block, which is supported by the main shaft. This pressure is effected by a cast-iron stand with phosphor-bronze liner. When the pistons are about half an inch from their terminal they strike against the rocking pressure wheel and are forced home. In this way the briquettes are made and the play repeats itself with every revolution.

The machine is entirely self-contained, and it is claimed that there is no possibility of its getting wrecked by overfeed or obstruction. It is also claimed that as the pressure is applied slowly and gradually this type of press permits briquetting mixtures containing 13 to 14 per cent of moisture, and that this is an advantage not possessed by intermittently acting presses. Up to the present time two styles have been made—one with two rows of 2-inch cylindrical molds and the other with two rows of 2½ by 2¾ inch rectangular shapes with rounded corners. There is no difficulty in making other shapes and heavier briquettes. A simple arrangement permits working with half the capacity whenever desired. No complications are presented if it is desired to have more than two rows of molds, and the press can be built for a much larger capacity. On the other hand, should the market for briquettes be lessened for some months in the year, the capacity can be cut down without requiring any change in speed or other alterations.

From 80 to 120 briquettes are made for each revolution, the number depending on the size and shape of the briquettes. These factors govern also the capacity, which ranges from 6 to 24½ tons per hour.

Mr. Schorr states that all wearing parts of the machine can be quickly and cheaply replaced. The lubricating is done by an air compressor and oil atomizer.

The press is especially adapted for the manufacture of small briquettes, and the advantages of such in preference to large blocks are obvious. Small briquettes can be readily shoveled into furnaces, whereas the large ones have first to be broken up, thus causing labor, waste, and dust.

A briquetting plant of an entirely different type, designed by Charles R. Allen, was built and put into operation by him during 1905 at Pittsburg, at the junction of San Joaquin and Sacramento

rivers, about 50 miles from San Francisco. This plant as originally projected was intended to utilize the subbituminous coal produced by the Pittsburg Coal Mining Company at Somersville, but the enormous increase in the production of oil in California has had so demoralizing an effect on the coal trade generally that there has been little or no market for the coal during the last two years and the mines have been shut down. The material used has been screenings obtained from the coal yards of San Francisco, the binder here, as at other plants in the State, being asphaltic pitch. The screenings are sold at less than the cost of mining coal, and as long as the supply of this material is available at such prices it will continue to be used.

The methods of preparing the briquetting mixture differ somewhat from those used at other plants, in that the binder, together with the fuel, is passed through the retorts under a high degree of heat. This it is claimed insures an intimate and thorough mixture, each particle of fuel being impregnated with the binder. This treatment it is asserted prevents the binder from being consumed before the coal is ignited, which is apt to be the case, particularly with subbituminous coal, if the mixing is merely superficial. Mr. Allen claims that in his process the nature of the fuel is changed so that the subbituminous coal partakes of the character of bituminous coal, the briquettes remaining firm and hard until entirely consumed. He claims also that the process possesses as much of novelty and value as the press.

The compressing machine consists of two nonconcentric rings horizontally placed one within the other, the periphery of the smaller one being corrugated, or scalloped, and engaging with similar corrugations in the inside of the larger ring. The briquetting mixture is fed into a hopper one-fourth of a revolution of the smaller ring from the point of compression, and the amount of pressure is regulated by the distance of the feed from the point of compression: that is to say, the hopper may be placed farther away if a greater pressure is desired, or nearer if the pressure is to be reduced. Relief from an excess of pressure is provided for by two heavy spiral springs on the outer bearings and two over the upper pressure plate, the lower pressure plate being fixed. The machine has been operated without using any of the springs, with the result that when there was a surplus of feed the operating belt was thrown off through the choking of the machine.

Mr. Allen's invention is United States patent No. 851007. The briquettes as now made are approximately cylindrical in shape, with flat ends. They weigh from 8 to 10 ounces each and have a specific gravity of 1.14. It is Mr. Allen's intention to reduce the size of the briquette and change its shape by having the smaller ring of the press made with no corrugations. This will be done in order to meet the demand for a briquette better adapted for domestic use.

The plant is at present turning out about 5 tons of briquettes per hour, at a moderate running speed. With a smaller briquette the production per hour would be decreased with the same speed, but by increasing the speed the same production could be maintained.

The Standard Coal Briquetting Company, of Oakland, constructed in 1905 a plant designed by a Mr. Crawford. An accident to the press shortly after being put in operation practically wrecked it and the enterprise was unsuccessful.

Another plant, beginning operations in 1905, used a small press of the plunger type, designed by A. Demetrak and built by the American Briquetting Company (afterwards reorganized as the Ajax Briquetting Company), of San Francisco. It was destroyed by the earthquake and fire of April, 1906, and has not been rebuilt. The plant had a capacity of about 15 tons a day, using subbituminous coal from Coos Bay, Oregon, sometimes mixed with coal-yard screenings and asphaltic pitch.

The United States Briquette Company, of Stege, Contra Costa County, has undertaken the manufacture of briquettes from a mixture of peat and California crude petroleum. This plant had not been completed at the time of writing this report, but some briquettes made of the mixture in an experimental way are interesting productions. They give promise of a method of using California oil as a domestic fuel, the peat on account of its spongy character acting as a carrying vehicle for the oil and at the same time performing duty as fuel. The briquettes are cubical in shape and of attractive appearance. They weigh about 10 ounces and have a specific gravity of 1.3. It is claimed that they are as well adapted for steam raising as for domestic purposes, giving an intense heat under forced draft and burning freely under ordinary draft; that they can be handled without waste from breakage, and that they leave a minimum amount of ash and do not clinker.

ARIZONA.

The Arizona Copper Company (Limited), of Clifton, Ariz., installed during 1905 a briquetting plant purchased from Yeadon, Son & Co., of Leeds, England. The plant was put into operation in September, 1905, and produced during the first six months of 1906, 690 short tons of briquettes having a total value of $4,830, or an average of $7 per ton. About 300 tons were produced in experimental runs in 1905. The plant was installed for the threefold purpose of utilizing coke breeze, which is without value and nonusable as such, of procuring better efficiency from the slack coal (Gallup, N. Mex.) which is used as fuel, and of obtaining a fuel that could be stored without material deterioration and without danger of spontaneous ignition. James Colquhoun, president of the company, states that the eco-

nomic advantages realized are from the first and third operations. By briquetting the coke fines or breeze a profit of about $4 per ton is made in the conversion of a material formerly wasted into a usable fuel. In using the Gallup slack, which is subbituminous coal ("black lignite"), the expense of briquetting brings the total cost up to approximately $6.80 per ton, or about the same as that of the lump coal obtained from the same source, although the price for the slack at the mines is very low compared with that of lump coal. The briquettes have been found to burn freely and satisfactorily under locomotive and stationary boilers, and appear to be equal to the best of Gallup lump coal, but no laboratory tests as to their calorific power have been made. The real profit in the briquetting of this coal lies in the superiority of the briquettes over lump coal for stacking purposes. They stand weathering perfectly, while the lump coal disintegrates on exposure, loses a portion of its combustible gases, and becomes in time a very inferior fuel. It is also liable to spontaneous combustion, which the briquettes are not.

In making the briquettes 92 per cent of the coal is mixed with 8 per cent of California asphaltic pitch. The capacity of the plant is 2½ tons of briquettes per hour.

The following description of the plant at Clifton has been furnished by the company. In design the press is similar to the one used by the Geological Survey fuel-testing plant at St. Louis. This was designated the "English" machine, and has been described in the reports of those tests.[a]

The coal or coke fines are fed from the bins into the boot of a bucket elevator, which discharges them into the hopper at one end of a mixer, where it is mixed with pitch that has previously been broken in a pitch breaker into pieces of one-half inch maximum size. The quantity of pitch found to give the best results is about 8 per cent. From the mixer the material is sent into a disintegrator, which thoroughly pulverizes the coal and pitch into grains of 2 mm. size or less. It is then elevated and passed into a heater, where it is subjected to the action of live steam, which gives the pitch sufficient fluidity to bind the other ingredients. From the heater the material drops into a pug mill, which, while stirring the mass, sweeps it into a false bottom. This false bottom is behind the disk of the briquetting machine, and at each revolution of the main shaft the material is rammed into a pair of compartments in the disk. The disk contains eight pairs of such compartments, and at the same time that a pair of briquettes is being rammed into the disk on one side another pair is being compressed on the opposite side, while a third pair is being pushed out from the top of the disk onto an endless-belt conveyor, which delivers

[a] Bull. U. S. Geol. Survey No. 261, and Prof. Paper No. 48, 1906.

the briquettes to the side of a railroad car in front of the building. The briquette disk is made to revolve intermittently in eight periods to each complete revolution. During the pause in each period the three operations referred to take place simultaneously.

The capacity of the plant is 25 tons per ten hours. It is arranged to mix three ingredients into material for briquettes, but at present only coal or coke fines and pitch are used. The briquettes are rectangular in shape and weigh approximately 4 pounds each.

MICHIGAN.

The Semet-Solvay Company, of Syracuse, N. Y., has recently completed the construction of a briquetting plant at Del Ray, Mich., to be operated in connection with the by-product coking ovens and chemical works installed there several years ago by the same company. The installation of the briquetting plant was begun about two and a half years ago. As originally constructed the briquetting machine was a reciprocating press of English make, but after carefully working out the process the company came to the conclusion that a press of the reciprocating type is adapted only to large briquettes, whereas the domestic trade of the city of Detroit, for which this product was intended, demands a small briquette. As the result of the experience gained with the English machine, the company has developed a process for the manufacture of small briquettes, and, although this plant is just beginning operations, it gives excellent promise.

The process consists, essentially, of the intimate mixing of finely powdered pitch of proper quality and consistency with pulverized coal, so that theoretically each particle of coal is coated with the fine pitch. The mixture is then brought up to the proper temperature with steam, or steam and hot water, and is fed to a rotary Mashek press built by the Traylor Engineering Company, of New York. The output of the plant is from 10 to 15 tons of briquettes per hour. They are from 2½ to 3 ounces in weight, and about 1⅞ inches square, shaped somewhat like a miniature sofa pillow. This shape is satisfactory for shoveling and for handling in household stoves and furnaces. The company is using a portion of coke breeze with the coal and pitch with a view of utilizing the breeze from its coke plant, and it is also experimenting on the best mixtures and the best grades of coal. The briquettes made so far are said to burn well and to give no smoke, except a slight puff when they are first thrown on the fire. As the plant is not yet in full operation, some minor adjustments are still being made to perfect the product, but the operators are much encouraged by results so far obtained, and expect within a short time to be making a thoroughly satisfactory commercial product.

NORTH DAKOTA.

During 1905 ex-United States Senator W. D. Washburn, president of the Washburn Lignite Coal Company, erected a small plant at Minneapolis, Minn., for experimental work in briquetting North Dakota lignite. The plant was too small to be operated successfully from a commercial standpoint. Several hundred tons of briquettes were made without the use of a binder. They proved a satisfactory fuel for domestic purposes and for stationary boilers, but were not adapted to locomotive use, as the heavy exhaust draft in the locomotive has the effect of disintegrating the briquette before combustion and causes the throwing off of large sparks.

Robert L. Stewart, also of Minneapolis, who is interested in lignite properties near Kenmare, Ward County, N. Dak., reports that he has been conducting a series of experiments with a view to briquetting this fuel, and as a result of his investigations the American Briquetting and Manufacturing Company has been organized. This company contemplates constructing, during the present year, a briquetting plant in North Dakota convenient to the lignite deposits and having a capacity of 1,000 tons of briquettes per day. Mr. Stewart states that the briquettes can be manufactured at a cost not to exceed $2 per ton f. o. b., this cost including the expense of mining the lignite and delivering it to the briquetting plant.

TEXAS.

Three companies have been organized recently in Texas for the purpose of briquetting lignite, which occurs in great abundance through the eastern part of that State. These are the International Compress Coal Company, of Houston; the American Lignite Briquette Company, of San Antonio; and the Eureka Briquette Company, of Rockdale. The plant of the Eureka Company has been erected and is ready for operation at the time of writing this report, except for the fact that the drying apparatus has been found too small and the plant has been shut down pending the erection of a larger drier. The details of the plant have not been obtained.

The American Lignite Briquette Company, while incorporated at San Antonio, will locate its plant at Rockdale, to be operated in connection with the lignite mines of J. J. Olsen & Son. The company has purchased a press made by the Klein Briquette Company, of St. Louis, Mo., and the plant will probably be in operation by the time this report is ready for distribution.

The International Compress Coal Company has been negotiating for the construction of a plant, but no actual building had been begun at the time of writing this report. All these plants expect to use asphaltic pitch made from heavy Texas oil.

FLORIDA.

In September, 1905, the Orlando Water and Light Company, of Orlando, Fla., completed the installation of a plant for the treatment and briquetting of peat, which occurs abundantly in the low-lying lands of Florida. The plant is located about 3 miles from Orlando, on the border of a peat bog from which its supply is drawn. As originally installed, this plant consisted of a macerating machine or pug mill, in which the fiber of the peat is entirely destroyed, and a brick press. The briquettes as they came from the press were about the size of an ordinary building brick, but when dried in the sun shrunk to about one-fourth their former bulk and lost from 75 to 85 per cent in weight. The briquetting feature of the plant was abandoned in the summer of 1906, as it was found that this part of the work represented 75 per cent of the total cost, and that a satisfactory fuel could be made without briquetting. The method of treatment at the present consists simply of "machining" the peat in the pug mill and dumping it in masses of several hundred tons. As the peat dries it shrinks and cracks into large, irregularly rectangular blocks, which are broken off from the heap and stored. When thoroughly dried, these blocks make a good hard fuel, which it is stated may be used for both locomotive and stationary boilers, for household purposes, and for the manufacture of gas. Tests of the machined peat for producer gas at the Geological Survey fuel-testing plant gave excellent results.[a]

The machine used at the Orlando plant was built by the Moore and Wyman Elevator and Machine Works, South Boston, Mass., under patents issued to the late T. H. Leavitt, of Boston.

MISSOURI.

During the summer of 1903 Gov. W. C. Renfrow, of Oklahoma, became financially interested in a briquetting company in St. Louis. In the fall of the same year E. D. Mizner, of Hamilton, Ontario, visited St. Louis to make a report for some Canadian interests relative to the purchase of the Canadian rights for the patents of this company. The results of these investigations, and the efforts of Governor Renfrow to force the briquette company to deliver a machine, ended in the bankruptcy of the company. In October, 1903, an agreement was made between Governor Renfrow and Mr. Mizner by which Mr. Mizner was to build a briquette machine which would overcome the difficulties encountered with the other press. No company was organized at that time, but contracts were drawn satisfactory to the people interested.

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[a] Campbell, M. R., Peat: Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906, p. 1320.

The following spring Mr. Mizner built the first Renfrow press, which made briquettes 2 inches in diameter, weighing about 4 ounces. This press had some of the essential features of the original Renfrow press, but made briquettes only at one end of the stroke—that is, 12 briquettes per revolution. After this machine was built it was discovered that the briquettes were too small and that the construction of the machine was too light. Mr. Mizner also developed the idea of making briquettes at both ends of the stroke, thus doubling the capacity of the machine. It was decided to build a much heavier machine, making a briquette 3 inches in diameter. Changes were also made in the method of mixing and heating the material. The cast-iron vertical heaters of the original press were supplanted with horizontal jacketed heaters, using ordinary spiral conveyor flights for mixing and handling the fuel. To this was added a short vertical heater, acting as a reservoir into which live steam was admitted just before the mixture was delivered to the molds.

This machine was completed in the fall of 1905. C. T. Malcolmson, of the Geological Survey testing plant,[a] inspected this press at the shops of the Ramming Machine Company, at St. Louis, and burned some of the briquettes under a boiler at that plant. Difficulties were developed from the fact that the fuel remained too long in the vertical heaters, and some trouble was also experienced in getting the material from the die filler to the die proper. Occasionally briquettes would stick in the dies, resulting in a double charge, which finally crippled the machine. Provision was then made to overcome these difficulties and the machine was rebuilt. The new machine was first tested in March, 1906. The heating capacity was increased so that the charge remained in the conveyors about fifteen minutes before reaching the dies, thus allowing the material to become thoroughly heated and the melted pitch to mix with the coal. Brushes were added to insure the charge being carried to its proper position in front of the die, and an ejector, operated by a magnet, effected the delivery of the briquettes from the ends of the plungers. Many of the parts of the machine were strengthened and steel and bronze were substituted for cast iron in the wearing parts. The results of the tests on this machine made under the supervision of Mr. Malcolmson for J. A. Holmes, expert in charge of the Geological Survey fuel-testing plant, at the company's testing plant, resulted in a contract for the rental of this machine by the Government. In May, 1906, the first success-

[a] The briquetting portion of the Geological Survey coal-testing plant at St. Louis during the exposition has already been described in Bulls. Nos. 261 and 290, and Prof. Paper No. 48. After the close of the exposition the American machine, installed by the National Compressed Fuel Company, of Chicago, was removed, and early in 1906 the remaining portion of the briquetting plant was destroyed by fire. In rebuilding the plant provision was made for the installation of a Renfrow briquette machine.

fully operating Renfrow machine was installed at the fuel-testing plant.

The results of the tests made on the Renfrow machine from May, 1906, to March, 1907, indicated that the design of this press was, in the main, satisfactory, and that the difficulties experienced were due almost entirely to bad or weak construction of the machine. This machine was the result of many changes, and it was impossible to strengthen some of the weak parts owing to the limited space, or to the fact that the size of the part was fixed by the original design.

The difficulties encountered in operating this machine at the fuel-testing plant soon indicated its weaknesses, and as a result the Renfrow Company designed and built two new presses, one of which was installed and is now being operated by the Western Coalette Fuel Company at Kansas City. The other is now ready for delivery to the Government fuel-testing plant at the Jamestown exposition. The new press makes a briquette 3¼ inches in diameter, weighing about a pound. The machine which was operated at the St. Louis fuel-testing plant could not be depended on to deliver more than 1,000 pounds pressure per square inch on the briquettes without seriously straining the frame of the press. The new machine will deliver a maximum pressure of about 2,500 pounds per square inch without straining. All the wearing parts not under pressure are made of bronze, so as to prevent corrosion; the dies are made of case-hardened steel and, owing to the abrasive action of the fuel, are kept clean and bright. The cams and rollers, which were originally made of chilled cast iron, are in the new machine made of case-hardened tool steel, and the design of the housing has been so changed that any of the parts can be removed without dismantling the machine. Provision has also been made to so feed the heaters that they will always run clean and at the same time keep a full load in the chamber above the die filler. This chamber, closed in the old machine, is open in the new, thus allowing the operator to regulate the supply of fuel to the press at all times. The plungers are arranged so as to make it practically impossible for a double charge to enter the press, and the length of the spring behind the plungers has been increased so that a double charge would not affect the press in any way.

Early in 1906 the Renfrow Briquette Machine Company was incorporated under the laws of the State of Missouri, with a capital of $1,000,000. W. C. Renfrow is president, J. M. Smith, secretary and treasurer, and E. D. Mizner superintendent, and it is a close corporation. The company will not offer for sale any machines until after the Kansas City plant has proved successful. So far as can be learned, the construction of the Kansas City plant was brought about by the willingness of J. H. Durkee, president of the Western Coalette Fuel

Company, to accept a Renfrow machine without a guaranty, simply on the strength of the work done at the fuel-testing plant. There are still, of course, some difficulties to be overcome, as is the case in the operation of any new plant, but in the main the mechanical operations of this plant are satisfactory, and the Renfrow Company has been able to deliver what it contracted to deliver. Financial difficulties have threatened the life of the plant under the present organization, but Governor Renfrow has stated that he will not allow this plant to fail for this reason. A contract has been signed to deliver one of the machines to a company at Detroit, but under the terms of the contract no date is fixed for the delivery of this machine, and no guaranty from the Renfrow Company has been required. Governor Renfrow is also authority for the statement that the Detroit machine will not be delivered until after the Kansas City plant has been successfully operated and put on a commercial basis.

The Renfrow Briquette Machine Company has no plant of its own, but has under serious consideration the establishment of a factory at St. Louis. All the machines above mentioned were built by machine shops under contract. The Kansas City machine was built by the Excelsior Tool and Machine Company at East St. Louis, and the other machines by the Ramming Machine Company, of St. Louis.

COST OF MANUFACTURE.

The cost of manufacture of briquettes at one of the plants in the State of New York is as follows:

[illegible]

Pitch		
[illegible] per cent of pitch, at $[illegible] per [illegible]	$0.60	
Deducting from [illegible] weight [illegible] pitch calculating pitch at $[illegible] per [illegible]	.30	
Net cost of pitch		$0.30
Fuel		
[illegible] briquettes, 4 tons per day [illegible] at $[illegible] per [illegible] per [illegible] of briquettes		.10
[illegible] at $[illegible] per ton=$7.50; per [illegible] briquettes		.075
Labor		
[illegible] per day	$5.00	
[illegible] do	3.50	
[illegible] do	1.75	
[illegible] do	3.50	
[illegible] do	1.75	
[illegible] do	1.75	
[illegible] do	1.75	
[illegible] do	1.75	
	20.75	
[illegible]		[illegible]

Miscellaneous:	
Wear and tear per ton of briquettes	$0.10
Lubricating oil per ton of briquettes	.01
Insurance per ton of briquettes	.005
Interest on capital invested—$40,000 at 6 per cent	.10
Office expense, telephone, stenographer, and stationery—$2,000 per annum	.09
	.99
Anthracite dust at $1.40 per long ton, per net ton of briquettes	1.25
Total cost of briquetting	2.24
Rebriquetting 3 per cent of breakage and abrasion, charging it back to plant as dust, per ton of briquettes	.06
Net cost per ton of briquettes	2.30
Wholesale selling price in bin	4.80
Net profit per short ton	2.50

THE IMPORTANCE OF UNIFORM AND SYSTEMATIC COAL-MINE SAMPLING.

By JOHN SHOBER BURROWS.

INTRODUCTION.

In determining the value of a coal deposit it is essential to know two things—(1) the amount of workable coal available and (2) the quality of that which is marketable. The first of these has been ascertained by well-established methods of surveying and prospecting, but the second is not so easily determined, although at first sight it might seem much more easy to pronounce on the quality of the coal when once it is taken from the mine than to determine its amount where it lies. The usual means of determining the quality has been to make a chemical analysis of a small sample of the coal, taken either from the bed itself or from a pile or car of coal that has been freshly mined; and although this seems to be an exceedingly simple matter, and great reliance has been placed on it, previous to 1904 little or no effort had been made to test its accuracy, and consequently its value was entirely unknown. Since that year, however, the United States Geological Survey, in connection with the fuel tests which it has made at St. Louis, has collected a large number of most valuable data on this important subject. These data have shown that sampling as ordinarily done is not reliable and that in most cases the chemical analysis of such a sample shows a much cleaner coal than is actually obtained in mining. Discrepancies of this nature are due largely to the human tendency to select the best coal for the sample, regardless of the amount of extraneous matter that will be likely to get into the commercial product through careless mining and handling.

Attention was first called to this matter by M. R. Campbell,[a] who, at the close of the St. Louis exposition, summed up the results of mine sampling as compared with car sampling in the first year's work of the fuel-testing plant. These results showed conclusively that a sample obtained by the usual method of mine sampling can not be relied on to represent the average commercial product of the mine. From the data obtained during the first year certain coefficients were determined for correcting mine samples, so that when sampling is done in a uniform and systematic manner the result can be relied upon to approx-

[a] Prof. Paper U. S. Geol. Survey No. 48, 1906, p. 142.

imate the quality of the commercial product. Later[b] Campbell verified his original conclusions by the data obtained in the more refined method of mine sampling adopted for the work of the fuel-testing plant in 1905.

The writer has been in active charge of mine sampling for the fuel-testing plant since the exposition tests were completed, and the present paper sums up the general results of all mine and car sampling that has been done in connection with the fuel-testing work since its establishment at St. Louis in September, 1904, to its completion in March, 1907. During this period the inspectors of the fuel-testing plant visited, personally inspected, and sampled the coal in 159 mines located in 23 different States. From each of these mines at least two mine samples were obtained and one or more cars of coal were shipped to St. Louis, where they were carefully sampled and tested. Inasmuch as all of the work of sampling from its inception up to the present time has been done on practically the same general plan, with only slight modifications in the matter of minor details, the results are entirely comparable, forming the greatest mass of such material that has ever been accumulated. Not only is the material valuable on account of the great number of samples involved, but also on account of the variations in quality, the samples ranging from the lowest grade of brown, woody lignite to anthracite coal. The sampling has also been done under a great variety of climatic conditions, ranging from midwinter temperature to the heat of summer and from the semiarid conditions of the plateau country of New Mexico and Wyoming to the more humid conditions of the Mississippi Valley and the excessive rainfall of the western front of the Cascade Mountains.

SAMPLING FOR GEOLOGICAL SURVEY FUEL-TESTING PLANT.

One of the important features of the work of the fuel-testing plant has been the method adopted for collecting the material to be tested. In organizing the work, in 1904, it was decided that coal in carloads for practical tests should be shipped under the personal supervision of an inspector and that the inspector should also secure small mine samples for chemical analysis; that when the cars of coal arrived at the testing plant a representative sample should be taken from each car in the manner provided, and that complete analyses of the mine and car samples should be made for the purpose of comparison.

CAR SAMPLING.

The cars of coal were unloaded into a roll crusher, with the rolls set 1½ inches apart, the coal falling into the boot of a bucket elevator. As the buckets of the elevator moved upward to the storage bin, a sample was taken by a man with a small shovel from about every

[b] Economic Geology, vol. 2, No. 1, January-February, 1907, p. 48.

eighth or tenth bucket, and the sampling was continued until the entire car was emptied. The sample, which was kept in a tightly covered iron bucket of 80 to 100 pounds capacity, was sent to the laboratory without further preparation and was pulverized and quartered down to the requisite size. Several trials of different methods of car sampling proved this to be the best for obtaining uniform results.

MINE SAMPLING.

The method of mine sampling has been practically uniform throughout, but from time to time minor changes have been made as experience demonstrated the possibility of improvement. In the work done in 1905 the principal change consisted in crushing the sample in the mine immediately after taking it, instead of carrying it outside, as had been done in 1904. The old method permitted the sample to lose some of its moisture, but this was largely obviated by crushing in the mine, where the atmospheric conditions are generally constant. Another important change consisted in taking larger samples and in weighing them to be sure that a sufficient amount of coal was obtained. More detailed records were kept by the samplers, showing for each sample a complete section of the coal bed, the parts included in the sample, the parts excluded as contrasted with the partings thrown out by the miner, the gross weight of the sample, and the length of time it was exposed to the atmosphere of the mine while being crushed and quartered and sealed in the can.

In detail the method of taking the mine samples used from the close of the St. Louis exposition to the completion of the series of tests in March, 1907, is as follows:

For mine sampling two or more places were selected at widely separated points in the mine where the coal bed had an average development and from which most of the coal was being mined for shipment. At one of these places the face was cleared of burned powder, loose coal, and dirt for about 5 feet, and insecure pieces of the roof were taken down to prevent their falling into the sample. The sampler then spread a waterproof blanket on the floor of the mine close up to the face of the coal and made a perpendicular cut from floor to roof, including in the sample everything but the parts of the bed discarded by the miner. Sufficient coal was cut to make not less than 5 pounds to the foot in height—that is, a sample weighing not less than 20 pounds would be cut from a 4-foot bed of coal and a sample weighing at least 30 pounds from a 6-foot bed. When shale or other partings were to be included in the sample, great care was exercised to cut them the full width and depth of the groove, in order to preserve the proper proportion of coal and extraneous matter. When the required amount of coal was obtained, a detailed measure-

ment was made of the section of the bed from top to bottom, every perceptible parting and variation in the section being noted. The parts of the bed not included in the sample were clearly shown in the record, and from these notes the value of the sample could be judged. The cuttings were at once weighed and then sifted through a screen with a half-inch mesh. The remaining lumps were broken on a portable bucking board, and this process of screening and breaking was continued until the entire sample would pass through the screen. The sample was then mixed by two men grasping the opposite corners of the blanket. They rolled the sample diagonally by raising one corner of the blanket at a time, thereby mixing the sample thoroughly. When the larger pieces of coal were evenly distributed throughout the mass, the sample was quartered down, and two opposite quarters were discarded. The remainder was then mixed as before, and if the sample was still too bulky to be conveniently handled it was again quartered down. The material finally remaining was spread into a circular mass about 2 inches deep on the blanket, and a small trowel was used to fill a sample can with portions from the circumference to the center of the mass around the entire circle. The can was then closed and hermetically sealed with insulating tape ready for mailing to the chemical laboratory. The weight of this can showed accurately what proportion of the original sample was preserved.

The entire process of sampling was carried on as rapidly as possible at the place in the mine where the sample was cut, the maximum time for cutting and preparing a large sample being about one hour. It was assumed that as the sampling was quickly done in the native atmosphere of the coal there would be little or no loss in moisture.

PROPOSED METHOD OF MINE SAMPLING.

In discussing the results of mine and car sampling for the testing plant for 1904 Campbell concluded that the efforts to make the mine samples correspond to commercial coal were unsuccessful, and he recommended an arbitrary method of determining what should and what should not be included in the sample, as follows:

> All material encountered in a cut across the face of the coal should be included in the sample, except partings or binders more than three-eighths of an inch in thickness, and lenses or concretions of sulphur or other impurities greater than 2 inches in maximum diameter and one-half inch in thickness.
>
> If the sample is wet it should be taken out of the mine and dried until all sensible moisture has been driven off.

The main difference between the method proposed by Campbell and the method used by the inspectors of the fuel-testing plant lies in the manner of excluding impurities. In the Campbell method, as stated above, partings or binders of a certain size are arbitrarily

discarded, whereas in the inspectors' method only the partings which are actually discarded by the miner are excluded from the sample. The method of imitating the miner would seem to be the best, but it requires very careful judgment, as no two miners can be relied on to discard the same partings consistently, even at mines where the most rigid regulations are in force for cleaning the coal. The results of sampling done in this way show a decided improvement as experience is gained, but the method depends too much on personal judgment, and therefore it is not recommended for general use. Campbell's proposed method seems to fulfill all the present requirements when used in conjunction with the coefficients given on page 512 of this paper, and should be followed where samples are taken for purposes of comparison.

ANALYTICAL RESULTS OF SAMPLING FOR GEOLOGICAL SURVEY FUEL-TESTING PLANT, 1905-1907.

TABULAR SUMMARY.

During the first year mainly run-of-mine coal was shipped to the testing plant, but since then other sizes have been accepted for various sorts of tests. This has afforded excellent opportunities to compare the mine samples with screened coal as well as with run-of-mine coal. Three tables have been prepared showing the impurities in the mine and car samples, and comparing the average of the mine samples with the average of the car samples. Table 1 includes only the results on samples of run-of-mine coal. Table 2 is composed entirely of results on screened-coal samples, including all samples that were shipped as lump, egg, nut, etc., as well as many other special sizes which were obviously neither run-of-mine nor slack coal. Table 3 is made up from the results on samples of coal that were shipped as slack or screenings.

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal.*

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Alabama No. 2 B, Carbon Hill:										
Mine sample	3011	4.71	10.17	1.33	4.61	9.54	1.40	0.66	.....	0.28
Do	3012	4.51	8.92	1.48						
Car sample	3211	3.95	14.59	1.12	3.95	14.59	1.12	.....	5.05	.....
Alabama No. 3, Garnsey:										
Mine sample	3018	3.03	10.72	.49	3.14	11.44	.51	.42	.....	.....
Do	3019	3.25	12.16	.53						
Car sample	3255	2.72	14.36	.55	2.72	14.36	.55	.....	2.92	.04
Alabama No. 4, Belle Ellen:										
Mine sample	3034	3.67	3.14	1.22	3.63	2.80	1.36	.....	.....	.28
Do	3035	3.60	2.46	1.50						
Car sample	3103	6.43	12.92	1.08	6.43	12.92	1.08	2.80	10.12	.....
Alabama No. 5, Lehigh:										
Mine sample	4090	4.72	4.14	.83	3.82	3.43	.74	.....	.....	.....
Do	4091	2.93	2.73	.65						
Car sample	4252	5.59	16.08	1.40	5.59	16.08	1.40	1.77	12.65	.66

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Alabama No. 6, Dolomite:										
Mine sample	4292	3.23	3.83	.57	3.02	3.67	0.58	.....	.....	.....
Do	4293	2.81	3.51	.59						
Car sample	4338	3.23	6.71	.61	3.39	6.83	.59	0.37	3.16	0.01
Do	4353	3.56	6.95	.58						
Arkansas No. 10, Lester:										
Mine sample	2647	39.50	12.58	.53	40.37	10.19	.51	.94	.48	.02
Do	2648	41.25	7.81	.50						
Car sample	2726	39.43	9.71	.49	39.43	9.71	.49	.....	.....	.....
California No. 1, Tesla:										
Mine sample	1606	17.59	18.03	2.89	17.80	17.20	2.98	.....	1.71	.....
Do	1607	18.02	16.37	3.07						
Car sample	1680	18.51	15.49	3.05	18.51	15.49	3.05	.71	.....	.07
Illinois No. 6 B, Coffeen:										
Mine sample	1661	12.90	11.08	3.78	12.90	11.08	3.78	.97	.....	.....
Car sample	1702	11.93	14.18	4.29	11.93	14.18	4.29	.....	3.10	.51
Illinois No. 7 D, Collinsville:										
Mine sample	1608	12.27	11.35	4.66	12.07	11.46	4.70	1.21	.....	.17
Do	1609	11.87	11.58	4.75						
Car sample	1780	10.86	13.18	4.53	10.86	13.18	4.53	.....	1.72	.....
Illinois No. 9 A, Staunton:										
Mine sample	1625	13.29	8.90	4.12	14.28	9.05	3.91	.74	.....	.....
Do	1626	15.27	9.20	3.70						
Car sample	1635	13.54	10.74	4.03	13.54	10.74	4.03	.....	1.69	.12
Illinois No. 11 B:										
Mine sample	1634	8.30	9.26	2.82	8.30	9.26	2.82	.....	.....	.36
Car sample	1660	8.86	11.66	2.46	8.86	11.66	2.46	.56	2.40	.....
Illinois No. 12, Bush:										
Mine sample	1683	8.29	10.83	2.81	8.35	11.35	3.22	.15	.....	.....
Do	1688	8.41	11.88	3.63						
Car sample	1762	8.20	12.95	3.48	8.20	12.95	3.48	.....	1.60	.26
Illinois No. 19 C, Zeigler:										
Mine sample	1871	9.90	7.74	.48	10.03	7.13	.47	.45	.....	.....
Do	1872	10.53	7.40	.47						
Do	3408	9.65	6.25	.45						
Car sample	3447	9.58	11.00	.52	9.58	11.00	.52	.....	3.87	.05
Illinois No. 25 A, Germantown:										
Mine sample	2856	11.64	8.66	3.41	11.89	8.97	3.71	.54	.....	.....
Do	2857	12.15	9.28	4.01						
Car sample	2991	11.35	13.40	4.76	11.35	13.40	4.76	.....	4.43	1.05
Illinois No. 26, Lincoln:										
Mine sample	2881	14.77	12.58	3.95	15.14	12.41	3.80	.....	.32	.29
Do	2882	15.52	12.35	3.65						
Car sample	3003	15.68	12.09	3.51	15.68	12.09	3.51	.54	.....	.....
Illinois No. 27, Auburn:										
Mine sample	2897	14.29	8.18	4.41	14.23	9.02	4.38	.....	.....	.33
Do	2898	14.18	9.86	4.36						
Car sample	3052	16.00	13.77	4.05	16.00	13.77	4.05	1.77	4.75	.....
Illinois No. 29 B, Livingston:										
Mine sample	3911	14.25	9.44	3.72	13.47	9.10	3.67	1.00	.....	.....
Do	3913	12.69	8.76	3.62						
Car sample	3958	12.47	12.56	4.37	12.47	12.56	4.37	.....	3.46	.70
Illinois No. 34 B, Harrisburg:										
Mine sample	4413	7.55	7.15	1.56	7.53	7.31	1.57	.....	.....	.....
Do	4414	7.51	7.48	1.58						
Car sample	4622	7.81	8.38	2.36	7.81	8.38	2.36	.28	1.07	.79
Indiana No. 5, Hymera:										
Mine sample	1773	12.14	8.96	3.54	12.15	9.06	4.10	.12	.....	.....
Do	1774	12.17	9.16	4.66						
Car sample	1859	12.03	10.88	4.27	12.03	10.88	4.27	.....	1.82	.17
Indiana No. 6, Hymera:										
Mine sample	1772	10.45	9.58	4.04	9.83	10.37	3.99	.....	.....	.....
Do	1776	9.22	11.17	3.94						
Car sample	1875	10.80	12.62	4.39	10.80	12.62	4.39	.97	2.25	.40
Indiana No. 9 B, Macksville:										
Mine sample	1848	13.73	8.65	3.00	14.03	8.56	2.85	.50	.....	.....
Do	1849	14.33	8.47	2.70						
Car sample	1960	13.53	10.76	3.15	13.53	10.76	3.15	.....	2.20	.30
Indiana No. 12, Hartwell:										
Mine sample	2701	11.29	6.87	3.09	11.19	7.69	3.47	.62	.....	.....
Do	2702	11.10	8.52	3.86						
Car sample	2759	10.57	11.65	3.87	10.57	11.65	3.87	.....	3.96	.40
Indiana No. 13, Terre Haute:										
Mine sample	3467	13.43	7.34	2.16	13.65	8.01	2.71	.86	.....	.....
Do	3468	13.88	8.69	3.26						
Car sample	3748	12.79	12.09	3.18	12.79	12.09	3.18	.....	4.08	.47

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Indiana No. 14, Seelyville:										
Mine sample	3491	13.62	7.11	3.28	12.54	8.90	4.36	4.66	.....	.....
Do	3492	11.46	10.70	5.45						
Car sample	3775	7.88	14.20	5.14	7.88	14.20	5.14	.....	5.30	0.78
Indiana No. 15, Linton:										
Mine sample	3473	13.53	7.55	.95	13.75	7.32	.95	.17	.....	.04
Do	3474	13.98	7.10	96						
Car sample	3567	13.58	8.15	.91	13.58	8.15	.91	.....	.83	.....
Indiana No. 16, Linton:										
Mine sample	3475	10.19	9.21	3.16	10.85	10.21	3.66	.55	.....	.....
Do	3476	11.51	11.22	4.17						
Car sample	3564	10.30	11.75	4.23	10.30	11.75	4.23	.....	1.54	.57
Indiana No. 17, Bicknell:										
Mine sample	3516	10.60	8.30	3.69	11.23	8.18	3.87	.....	.....	.22
Do	3517	11.87	8.06	4.05						
Car sample	3981	12.08	11.02	3.65	12.08	11.02	3.65	.85	2.84	.....
Kentucky No. 5, Head of Big Looney Creek:										
Mine sample	2271	4.45	3.23	.54	4.49	2.66	.52	.13	.....	.....
Do	2272	4.72	2.48	.54						
Do	2270	4.32	2.28	.48						
Car sample	2528	4.36	3.70	.67	4.36	3.70	.67	.....	1.04	.15
Kentucky No. 6, Paintsville:										
Mine sample	2405	6.95	2.03	.48	6.73	2.14	.46	1.61	.....	.....
Do	2406	6.52	2.26	.45						
Car sample	2592	5.12	2.76	.57	5.12	2.76	.57	.....	.62	.11
Kentucky No. 8, Sturgis:										
Mine sample	3678	7.46	4.60	.97	7.77	4.88	1.02	2.31	.....	.....
Do	3679	8.09	5.16	1.07						
Car sample	3860	5.46	7.92	1.18	5.46	7.92	1.18	.....	3.04	.16
Kentucky No. 9 B, McHenry:										
Mine sample	3722	10.03	7.67	2.56	9.96	8.18	2.50	1.92	.....	.....
Do	3723	9.89	8.69	2.45						
Car sample	4211	8.04	10.05	2.97	8.04	10.05	2.97	.....	1.87	.47
Maryland No. 1, Piedmont, W.Va.:										
Mine sample	2018	2.47	9.55	1.23	2.96	10.20	1.41	.63	.....	.....
Do	2019	3.45	10.85	1.60						
Car sample	2274	2.33	13.13	1.49	2.33	13.13	1.49	.....	2.93	.08
Maryland No. 2, Frostburg:										
Mine sample	4334	2.54	6.14	.87	2.50	6.22	.83	.....	.....	.....
Do	4335	2.47	6.30	.79						
Car sample	4386	3.42	7.09	.84	3.42	7.09	.84	.92	.87	.01
Missouri No. 5, Higbee:										
Mine sample	2795	13.38	10.02	4.48	13.63	10.72	4.33	.71	.....	.....
Do	2796	13.89	11.52	4.19						
Car sample	2865	12.92	13.62	5.03	12.92	13.62	5.03	.....	2.90	.70
New Mexico No. 3 A, Van Houten:										
Mine sample	3221	2.50	9.13	.72	2.98	10.02	.68	.....	.....	.....
Do	3222	3.48	12.92	.64						
Car sample	3295	3.45	16.67	.73	3.45	16.67	.73	.47	6.65	.05
New Mexico No. 4 A, Brilliant:										
Mine sample	3228	2.19	11.11	.57	2.43	10.46	.57	.....	.....	.....
Do	3229	2.67	9.82	.58						
Car sample	3331	2.78	14.57	.61	2.78	14.57	.61	.35	4.11	.04
New Mexico No. 5, Blossburg:										
Mine sample	3226	2.25	12.37	.75	2.28	12.73	.70	.....	.....	.01
Do	3227	2.31	13.10	.66						
Car sample	3294	2.72	14.57	.69	2.72	14.57	.69	.44	1.84	.....
North Dakota No. 3, Wilton:										
Mine sample	1935	40.53	5.05	.76	41.20	5.16	.86	5.24	.....	.....
Do	1938	41.88	5.28	.96						
Car sample	2243	35.96	7.75	1.15	35.96	7.75	1.15	.....	2.59	.29
Ohio No. 1, Wellston:										
Mine sample	1896	8.45	6.73	3.10	7.97	8.62	4.27	.26	.....	.....
Do	1897	7.50	10.51	5.44						
Car sample	2071	7.71	11.95	4.61	7.71	11.95	4.61	.....	3.33	.34
Ohio No. 2, Wellston:										
Mine sample	1898	9.38	7.62	4.08	9.16	8.48	4.24	.15	.....	.22
Do	1899	8.95	9.34	4.41						
Car sample	2109	9.01	11.34	4.02	9.01	11.34	4.02	.....	2.86	.....
Ohio No. 3, Shawnee:										
Mine sample	1900	10.78	6.13	1.11	10.27	6.07	1.27	.37	.....	.....
Do	1901	9.79	6.01	1.43						
Car sample	2144	9.90	11.58	1.81	9.90	11.58	1.81	.....	5.51	.54
Ohio No. 6, Neff's:										
Mine sample	2095	3.99	8.07	3.49	4.02	7.25	3.42	.....	.....	.09
Do	2096	4.06	6.44	3.35						
Car sample	2392	5.31	8.52	3.33	5.31	8.52	3.33	1.29	1.27	.....

Table 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Ohio No. 8, Dixie:										
Mine sample	2119	8.92	5.85	3.00	8.89	4.92	2.37	1.34	.....	.....
Do	2120	8.87	4.00	1.74						
Car sample	2559	7.55	8.37	2.84	7.55	8.37	2.84	.....	3.45	0.47
Ohio No. 12, Bellaire:										
Mine sample	3987	3.32	6.77	3.55	3.21	6.40	3.48	.....	.....	.....
Do	3988	3.10	6.03	3.42						
Car sample	4151	4.14	9.38	3.96	3.55	9.67	3.80	.34	3.27	.32
Do	4178	2.97	9.97	3.65						
Pennsylvania No. 6, East Millsboro:										
Mine sample	1968	4.08	9.50	1.64	3.44	9.06	1.82	.09	.....	.....
Do	1970	2.81	8.63	2.00						
Car sample	2161	3.24	12.52	1.94	3.35	12.76	1.94	.....	3.70	.12
Do	2176	3.46	13.00	1.95						
Pennsylvania No, 7. Ligonier:										
Mine sample	1994	3.30	11.18	1.79	3.04	11.95	1.83	.....	.....	.....
Do	1995	2.78	12.73	1.88						
Car sample	2154	4.09	12.47	2.08	4.09	12.47	2.08	1.05	.52	.25
Pennsylvania No. 8, Ehrenfeld:										
Mine sample	2014	3.49	5.71	.95	3.29	5.58	1.06	.....	.....	.12
Do	2015	3.09	5.46	1.18						
Car sample	2152	3.51	6.63	.94	3.51	6.63	.94	.22	1.05	.....
Pennsylvania No. 9, Kimmelton:										
Mine sample	2016	2.63	10.21	2.05	3.26	9.27	1.90	.17	.....	.....
Do	2017	3.90	8.33	1.76						
Car sample	2199	3.09	11.33	2.04	3.09	11.33	2.04	.....	2.06	.14
Pennsylvania No. 11, Charlerol:										
Mine sample	3421	2.50	5.34	1.14	2.53	6.14	1.70	.58	.....	.52
Do	3422	2.56	6.95	2.27						
Car sample	3532	1.95	7.29	1.18	1.95	7.29	1.18	.....	1.15	.....
Pennsylvania No. 12, Atcheson:										
Mine sample	3441	2.60	5.63	1.19	2.90	5.75	1.20	.94	.....	.....
Do	3442	3.21	5.88	1.22						
Car sample	4098	1.96	9.25	2.19	1.96	9.25	2.19	.....	3.50	.99
Pennsylvania No. 13, Creighton:										
Mine sample	3437	2.53	8.98	2.21	2.73	8.25	2.04	.08	.....	.....
Do	3438	2.93	7.53	1.87						
Car sample	3879	2.65	13.16	2.16	2.65	13.16	2.16	.....	4.91	.12
Pennsylvania No. 15, Wehrum:										
Mine sample	4026	3.83	9.25	4.57	3.33	8.76	3.84	.48	.....	.....
Do	4027	2.84	8.27	3.11						
Car sample	4082	3.13	9.81	3.77	2.85	10.07	3.87	.....	1.31	.03
Do	4104	2.57	10.33	3.97						
Pennsylvania No. 16, Hastings:										
Mine sample	4028	2.86	6.79	1.42	2.80	7.01	1.46	.....	.....	.....
Do	4029	2.74	7.23	1.51						
Car sample	4169	4.25	7.87	1.59	4.25	7.87	1.59	1.45	.86	.13
Pennsylvania No. 17, White:										
Mine sample	4336	2.22	7.20	1.39	2.22	7.81	1.46	.....	.....	.....
Do	4337	2.22	8.42	1.54						
Car sample	4421	4.35	11.90	1.51	4.35	11.90	1.51	2.13	4.09	.05
Pennsylvania No. 18, Lloydell:										
Mine sample	4347	2.43	6.61	1.34	2.54	7.58	2.15	.....	.....	.66
Do	4348	2.66	8.56	2.97						
Car sample	4509	4.46	8.47	1.49	4.46	8.47	1.49	1.92	.89	.....
Pennsylvania No. 19, Herminie:										
Mine sample	4351	2.81	6.27	.99	2.41	6.29	1.19	.....	.....	.14
Do	4352	2.01	6.32	1.39						
Car sample	4489	3.39	8.36	1.05	3.39	8.36	1.05	.98	2.07	.....
Pennsylvania No. 20, Seward:										
Mine sample	4349	2.80	7.96	2.29	2.64	8.60	2.66	.....	.....	.....
Do	4350	2.48	9.24	3.03						
Car sample	4517	4.00	10.54	2.85	4.00	10.54	2.85	1.36	1.94	.19
Pennsylvania No. 21, Connellsville:										
Mine sample	4412	2.82	7.37	1.22	2.61	7.29	1.09	.....	.....	.23
Do	4411	2.40	7.22	.97						
Car sample	4609	5.13	8.71	.86	5.13	8.71	.86	2.52	1.42	.....
Tennessee No. 1, Fork Ridge:										
Mine sample	2907	3.71	4.74	1.28	3.68	5.78	1.13	.....	.....	.....
Do	2908	3.66	6.83	.99						
Car sample	3016	4.81	11.15	1.58	4.81	11.15	1.58	1.13	5.37	.45
Tennessee No. 2, Gatliff:										
Mine sample	2931	3.61	3.41	.83	3.40	2.89	.85	.....	.....	.....
Do	2932	3.19	2.38	.88						
Car sample	3129	5.09	6.81	.98	5.09	6.81	.98	1.69	3.92	.13

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Tennessee No. 3, Gatliff:										
Mine sample	2929	4.25	4.13	.93	4.33	3.41	0.86	.....	.....	.....
Do.	2930	4.42	2.70	.80						
Car sample	3040	5.38	7.05	.99	5.38	7.05	.99	1.05	3.64	0.13
Tennessee No. 4, Oliver Springs:										
Mine sample	2956	3.25	6.61	.85	3.18	6.41	.85	.....	.....	.....
Do.	2957	3.12	6.21	.86						
Car sample	3058	6.39	9.53	.98	6.39	9.53	.98	3.21	3.12	.13
Tennessee No. 5, Petros:										
Mine sample	2958	2.25	6.91	2.96	2.22	7.55	3.40	.....	.....	.17
Do.	2959	2.20	8.20	3.84						
Car sample	3050	5.59	9.76	3.23	5.59	9.76	3.23	3.37	2.21	.....
Tennessee No. 6, Waldencia:										
Mine sample	2977	3.80	4.50	.78	3.40	5.33	.93	.....	.....	.15
Do.	2978	3.00	6.16	1.08						
Car sample	3102	3.89	14.43	.78	3.89	14.43	.78	.49	9.10	.....
Tennessee No. 7 A, Wilder:										
Mine sample	2979	3.46	9.08	2.42	3.25	9.60	3.13	.22	.....	.....
Do.	2980	3.04	10.13	3.84						
Car sample	3133	3.03	12.85	3.26	3.03	12.85	3.26	.....	3.25	.13
Tennessee No. 8, Clifty:										
Mine sample	3005	3.01	10.76	3.42	3.12	10.96	3.50	.25	.....	.....
Do	3006	3.23	11.16	3.58						
Car sample	3127	2.63	13.42	4.38	2.87	13.77	4.56	.....	2.81	1.06
Do.	3128	3.12	14.12	4.74						
Texas No. 4, Hoyt Station:										
Mine sample	2635	36.80	6.25	.53	35.83	6.94	.52	1.98	.....	.01
Do.	2636	34.87	7.64	.50						
Car sample	2717	33.85	7.30	.51	33.85	7.30	.51	.....	.36	....
Virginia No. 1, Crab Orchard:										
Mine sample	2246	4.72	4.63	2.55						
Do.	2268	5.69	8.11	2.31	5.65	5.71	1.89	1.30	.84	.74
Do.	2269	6.55	4.40	.80						
Car sample	2504	4.64	5.01	1.11	4.35	4.87	1.15	.....	.....	.....
Do.	2420	4.06	4.73	1.20						
Virginia No. 2, Crab Orchard:										
Mine sample	2248	3.90	5.06	.90	5.35	3.49	.79	2.00	.....	.....
Do.	2249	6.80	1.93	.68						
Car sample	2476	3.35	5.58	.92	3.35	5.58	.92	.....	2.09	.13
Virginia No. 6, Richlands:										
Mine sample	4304	3.03	4.62	1.70	2.81	4.55	1.52	.....	.....	.31
Do.	4305	2.60	4.48	1.35						
Car sample	4573	5.62	9.79	1.21	5.62	9.79	1.21	2.81	5.24	.....
Washington No. 1, Renton:										
Mine sample	2455	16.18	8.86	.46	17.07	8.32	.44	2.77	.....	.....
Do.	2456	17.97	7.78	.43						
Car sample	2686	14.30	11.37	.72	14.30	11.37	.72	.....	3.05	.28
West Virginia No. 4 B, Bretz:										
Mine sample	2054	3.57	6.21	.85	3.52	5.69	.82	.....	.....	.....
Do.	2055	3.47	5.18	.80						
Car sample	2250	3.91	10.11	1.07	3.91	10.11	1.07	.39	4.42	.25
West Virginia No. 13, Page:										
Mine sample	1867	5.48	2.29	.79						
Do.	1868	2.93	4.95	1.22	3.74	3.88	1.14	.....	.....	.25
Do.	2177	2.82	4.41	1.40						
Car sample	2028	3.74	3.91	.89	3.74	3.91	.89	.....	.03	.....
West Virginia No. 14, Page:										
Mine sample	1869	3.53	2.34	.92						
Do.	1870	2.96	7.44	1.04	3.53	5.74	.92	.....	2.47	.....
Do.	2178	4.11	7.45	.80						
Car sample	2004	5.09	3.27	1.03	5.09	3.27	1.03	1.56	.....	.11
West Virginia No. 15, Clarksburg:										
Mine sample	2039	2.80	5.55	2.40	3.03	5.64	2.40	1.02	.....	.....
Do.	2040	3.27	5.74	2.41						
Car sample	2195	2.01	8.55	2.54	2.01	8.55	2.54	.....	2.91	.14
West Virginia No. 17, Bretz:										
Mine sample	2056	3.22	7.33	1.73	3.63	6.46	1.44	.17	.....	.....
Do.	2057	4.05	5.60	1.16						
Car sample	2332	3.46	8.12	1.45	3.46	8.12	1.45	.....	1.66	.01
West Virginia No. 18, Glen Alum:										
Mine sample	2348	2.81	6.50	.66	3.42	5.83	.65	.56	.....	.....
Do.	2349	4.04	5.16	.64						
Car sample	2527	2.86	5.83	.67	2.86	5.83	.67	.....	.....	.02
West Virginia No. 19, Macdonald:										
Mine sample	2359	3.26	2.46	.78	3.38	2.50	.65	.42	.....	.....
Do.	2360	3.51	2.55	.53						
Car sample	2549	2.96	5.01	.89	2.96	5.01	.89	.....	2.51	.24

TABLE 1.—*Classification of impurities in mine and car samples of run-of-mine coal*—Continued.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
West Virginia No. 20, Acme:										
Mine sample	2375	2.66	4.44	1.14	2.75	4.83	1.24	.....	.....	.....
Do	2376	2.84	5.23	1.35						
Car sample	2556	2.82	8.03	1.38	2.85	7.83	1.44	0.10	3.00	0.20
Do	2626	2.89	7.63	1.50						
West Virginia No. 21, Winifrede:										
Mine sample	2377	3.57	3.62	1.14	3.64	3.87	1.15	.07	.....	.....
Do	2378	3.72	4.12	1.16						
Car sample	2572	3.57	4.85	1.32	3.57	4.85	1.32	.....	.98	.17
West Virginia, No. 22 B, Hernshaw:										
Mine sample	3456	2.75	5.49	.63	3.12	5.96	.63	.....	.....	.....
Do	3457	3.49	6.44	.63						
Car sample	3905	3.42	7.82	.83	3.42	7.82	.83	.30	1.86	.20
West Virginia No. 23 A, Monarch:										
Mine sample	3458	3.13	3.54	.59	3.65	4.92	.91	1.60	.....	.....
Do	3459	4.17	6.30	1.24						
Car sample	3965	2.05	8.10	1.35	2.05	8.10	1.35	.....	3.18	.44
Wyoming No. 2 B, Cambria:										
Mine sample	1376	8.60	21.90	4.94	8.91	21.43	4.63	.....	.64	.60
Do	1377	9.23	20.97	4.33						
Car sample	2131	8.93	20.79	4.03	8.93	20.79	4.03	.02	.....	.....
Wyoming No. 3, Aladdin:										
Mine sample	1976	17.74	11.55	7.03	18.08	10.82	6.88	2.96	.....	.22
Do	1977	18.42	10.10	6.73						
Car sample	2278	15.12	16.70	6.66	15.12	16.70	6.66	.....	5.88	.....
Wyoming No. 4, Hanna:										
Mine sample	3160	12.32	5.19	.23						
Do	3161	12.66	3.88	.21	12.05	5.13	.29	.75	.....	.01
Do	3162	11.49	5.89	.44						
Do	3163	11.73	5.57	.29						
Car sample	3363	11.30	7.31	.28	11.30	7.31	.28	.....	2.18	.....
Wyoming No. 5, Rock Springs:										
Mine sample	3165	13.10	3.34	1.04	12.75	2.93	.92	1.11	.....	.11
Do	3164	12.41	2.52	.80						
Car sample	3213	11.64	3.41	.81	11.64	3.41	.81	.....	.48	.....
Wyoming No. 6, Kemmerer:										
Mine sample	3202	20.57	2.63	.51	20.72	2.59	.52	1.72	.....	.03
Do	3203	20.88	2.56	.54						
Car sample	3390	19.00	3.12	.49	19.00	3.12	.49	.....	.53	.....
Average, mine samples	.....	.....	.....	.....	8.01	7.54	2.04	1.01	1.08	.24
Average, car samples	.....	.....	.....	.....	7.92	10.21	2.16	1.17	2.98	.28
Number of mine samples	.....	.....	.....	.....	87	87	87	50	6	28
Number of car samples	.....	.....	.....	.....	87	87	87	36	80	59

TABLE 2.—*Classification of impurities in mine and car samples of screened coal.*

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Arkansas No. 7 A, Midland (lump):										
Mine sample	2593	3.97	5.91	1.53	4.67	7.37	2.36	.....	.....	0.34
Do	2594	5.38	8.84	3.20						
Car sample	2688	5.47	11.69	2.02	5.47	11.69	2.02	0.80	4.32	.....
Arkansas No. 8, Spadra (No. 4):										
Mine sample	2587	3.12	8.46	1.84	2.92	8.41	2.31	.....	.....	.26
Do	2588	2.72	8.37	2.78						
Car sample	2744	5.19	14.01	2.05	5.19	14.01	2.05	2.27	5.60	.....
Georgia No. 1, Menlo (lump):										
Mine sample	4155	2.40	9.34	1.12	2.62	8.59	.89	.....	.....	.....
Do	4156	2.85	7.84	.67						
Car sample	4320	3.80	14.49	1.27	3.80	14.49	1.27	1.18	5.90	.38
Illinois No. 7 B, Collinsville (nut):										
Mine sample	1608	12.27	11.35	4.66	12.07	11.46	4.70	.61	.....	.30
Do	1609	11.87	11.58	4.75						
Car sample	1611	11.46	17.31	4.40	11.46	17.31	4.40	.....	5.85	.....
Illinois No. 9 B, Staunton (lump):										
Mine sample	1625	13.29	8.90	4.12	14.28	9.05	3.91	.56	.....	.....
Do	1626	15.27	9.20	3.70						
Car sample	1639	13.72	10.32	3.96	13.72	10.32	3.96	.....	1.27	.05

TABLE 2.—*Classification of impurities in mine and car samples of screened coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Illinois No. 11 A, Carterville (egg):										
Mine sample	1634	8.30	9.26	2.82	8.30	9.26	2.82	0.54	.....	0.85
Car sample	1654	7.76	10.61	1.97	7.76	10.61	1.97	.....	1.35	.....
Illinois No. 13, Benton (egg):										
Mine sample	1695	10.28	7.94	1.06	9.87	8.03	1.34	1.56	.....	.....
Do	1694	9.46	8.12	1.63						
Car sample	1786	8.31	10.48	1.55	8.31	10.48	1.55	.....	2.45	.21
Illinois No. 14, Springfield (lump):										
Mine sample	1704	13.89	11.26	3.83	14.17	10.96	3.64	1.40	.....	.....
Do	1705	14.45	10.66	3.46						
Car sample	1740	12.77	11.78	4.16	12.77	11.78	4.16	.....	.82	.52
Illinois No. 15, Centralia (lump):										
Mine sample	1725	10.25	12.53	3.70	11.06	10.68	3.47	1.11	.....	.....
Do	1726	11.88	8.83	3.25						
Car sample	1761	9.95	13.23	3.87	9.95	13.23	3.87	.....	2.55	.40
Illinois No. 16, Herrin (lump and egg):										
Mine sample	1731	9.37	7.37	1.25	8.98	7.17	1.51	.55	.....	.37
Do	1732	8.59	6.97	1.78						
Car sample	1820	8.43	9.60	1.14	8.43	9.60	1.14	.....	2.43	.....
Illinois No. 18, La Salle (lump):										
Mine sample	1741	13.87	10.31	3.44	14.71	8.94	3.22	2.32	.02	.....
Do	1742	15.55	7.58	3.01						
Car sample	1779	12.39	8.92	3.92	12.39	8.92	3.92	.....	.....	.70
Illinois No. 19 A, Zeigler (lump):										
Mine sample	1871	9.90	7.74	.48	10.21	7.57	.47	.....	.....	.....
Do	1872	10.53	7.40	.47						
Car sample	1926	14.91	8.93	.52	14.91	8.93	.52	4.70	1.36	.05
Illinois No. 19 B, Zeigler (lump):										
Mine sample	1871	9.90	7.74	.48	10.21	7.57	.47	.....	.....	.....
Do	1872	10.53	7.40	.47						
Car sample	2020	10.72	9.36	.91	10.72	9.36	.91	.51	1.79	.44
Illinois No. 19 D, Zeigler (lump):										
Mine sample	1871	9.90	7.74	.48	10.21	7.57	.47	1.34	.....	.....
Do	1872	10.53	7.40	.47						
Car sample	3448	9.45	9.07	.60	8.87	9.82	.56	.....	2.25	.09
Do	3451	8.30	10.57	.52						
Illinois No. 21, Troy (lump):										
Mine sample	2770	15.23	9.03	1.59	16.51	10.06	1.49	1.28	.....	.26
Do	2771	17.79	11.09	1.40						
Car sample	2852	15.54	10.93	1.38	15.23	11.21	1.23	.....	1.15	.....
Do	3015	14.92	11.49	1.09						
Illinois No. 22 A, Maryville (lump):										
Mine sample	2772	13.51	10.15	4.01	13.67	9.96	4.05	1.76	.....	.....
Do	2773	13.83	9.77	4.10						
Car sample	2905	11.91	13.01	5.34	11.91	13.01	5.34	.....	3.05	1.29
Illinois No. 22 B, Maryville (nut, pea, and slack):										
Mine sample	2772	13.51	10.15	4.01	13.67	9.96	4.06	.64	.....	.....
Do	2773	13.83	9.77	4.10						
Car sample	2896	13.03	14.53	4.35	13.03	14.53	4.35	.....	4.57	.29
Illinois No. 23 A, Donkville (lump):										
Mine sample	2774	13.07	10.06	3.59	12.92	10.67	3.76	.....	.....	.....
Do	2775	12.79	11.29	3.94						
Car sample	2819	13.47	11.53	4.41	13.47	11.53	4.41	.55	.86	.65
Illinois No. 23 B, Donkville (screenings):										
Mine sample	2774	13.07	10.06	3.59	12.93	10.67	3.76	.....	.....	.....
Do	2775	12.79	11.29	3.94						
Car sample	2803	15.68	15.59	3.98	15.68	15.59	3.98	2.75	4.92	.22
Illinois No. 24 B, New Baden (lump):										
Mine sample	2854	13.43	9.18	3.35	13.08	9.39	3.47	1.64	.....	.....
Do	2855	12.73	9.60	3.60						
Car sample	2972	11.44	10.71	4.94	11.44	10.71	4.94	.....	1.32	1.47
Illinois No. 28 B, Herrin (screenings):										
Mine sample	3629	8.72	7.62	1.00	8.80	7.82	.99	2.99	.....	.....
Do	3632	8.88	8.03	.99						
Car sample	2141	5.81	10.92	2.03	5.81	10.92	2.03	.....	3.10	1.04
Illinois No. 28 C, Herrin (lump):										
Mine sample	3629	8.72	7.62	1.00	8.80	7.82	.99	1.02	.....	.....
Do	3632	8.88	8.03	.99						
Car sample	3789	7.78	9.98	1.32	7.78	9.98	1.32	.....	2.16	.33
Illinois No. 29 A, Livingston (screenings):										
Mine sample	3911	14.25	9.44	3.72	13.47	9.20	3.67	.37	.....	.....
Do	3913	12.60	8.76	3.62						
Car sample	3963	13.10	16.00	4.17	13.10	16.00	4.17	.....	6.80	.50

TABLE 2.—*Classification of impurities in mine and car samples of screened coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Illinois No. 30, Shiloh Station (nut):										
Mine sample	3910	10.73	9.26	4.12	10.30	10.03	3.97	.....	.....	.....
Do	3912	9.88	10.81	3.83						
Car sample	4364	11.69	13.19	4.38	11.69	13.19	4.38	1.39	3.16	0.41
Illinois No. 31, Worden (screenings):										
Mine sample	4251	14.38	8.75	3.13	13.77	9.52	3.17	.67	.....	.....
Do	4250	13.17	10.29	3.22						
Car sample	4376	13.10	13.25	3.66	13.10	13.25	3.66	.....	3.73	.49
Illinois No. 34 A, Harrisburg (screenings):										
Mine sample	4413	7.55	7.15	1.56	7.53	7.31	1.57	.....	.....	.....
Do	4414	7.51	7.48	1.58						
Car sample	4636	9.33	11.89	2.76	9.33	11.89	2.76	1.80	4.58	1.19
Indiana No. 3, Boonville (nut):										
Mine sample	1759	11.28	7.63	3.58	11.19	8.65	3.95	.....	.....	.....
Do	1760	11.10	9.68	4.33						
Car sample	1941	13.18	15.63	4.79	13.18	15.63	4.79	1.99	6.98	.84
Indiana No. 4, Star City (screenings):										
Mine sample	1775	14.86	7.35	2.26	14.11	7.38	2.18	.12	.....	.....
Do	1807	13.37	7.42	2.10						
Car sample	1844	13.99	14.32	2.31	13.99	14.32	2.31	.....	6.94	.13
Indiana No. 7 A, Littles (lump, egg, and nut):										
Mine sample	1824	10.18	8.12	3.96	10.08	8.05	3.60	1.18	.....	.....
Do	1825	9.99	7.97	3.25						
Car sample	1881	8.90	9.21	3.74	8.90	9.21	3.74	.....	1.16	.14
Indiana No. 7 B, Littles (screenings):										
Mine sample	1824	10.18	8.12	3.96	10.08	8.05	3.60	.....	.....	.....
Do	1825	9.99	7.97	3.25						
Car sample	1882	11.12	9.35	3.78	11.12	9.35	3.78	1.04	1.30	.18
Indiana No. 8, West Terre Haute (lump):										
Mine sample	1828	10.68	12.24	4.38	10.90	11.22	4.07	1.35	.61	.35
Do	1829	11.13	10.21	3.76						
Car sample	2037	9.55	10.61	3.72	9.55	10.61	3.72	.....	.....	.....
Indiana No. 9 A, Mocksville (lump):										
Mine sample	1848	13.73	8.65	3.00	14.03	8.56	2.85	1.21	.....	.....
Do	1849	14.33	8.47	2.70						
Car sample	1973	12.82	10.30	3.27	12.82	10.30	3.27	.....	1.74	.42
Indiana No. 10, Rosedale (lump):										
Mine sample	1853	11.54	9.62	4.41	11.90	8.97	4.56	1.18	.40	.73
Do	1854	12.26	8.32	4.71						
Car sample	1979	10.72	8.57	3.83	10.72	8.57	3.83	.....	.....	.....
Indiana No. 11, Dugger (lump):										
Mine sample	1883	14.23	5.72	.89	13.42	6.35	1.62	1.27	.....	.21
Do	1884	12.62	6.98	2.35						
Car sample	2087	12.15	8.14	1.41	12.15	8.14	1.41	.....	1.79	.....
Indiana No. 18 B, Winslow (lump):										
Mine sample	3525	12.88	6.14	1.70	13.35	6.08	1.55	2.22	.....	.....
Do	3526	13.83	6.02	1.41						
Car sample	3801	11.13	6.98	1.64	11.13	6.98	1.64	.....	.90	.09
Indiana No. 19 Diamond (screenings):										
Mine sample	3534	13.70	5.91	2.66	13.82	5.49	2.29	4.73	.....	.....
Do	3535	13.93	5.07	1.93						
Car sample	4230	9.09	15.60	3.04	9.09	15.60	3.04	.....	10.11	.75
Indiana No. 20, Perth (screenings):										
Mine sample	3536	15.38	5.88	1.95	15.64	5.36	1.58	.....	.....	.....
Do	3537	15.91	4.85	1.22						
Car sample	3979	16.91	17.37	1.89	16.91	17.37	1.89	1.27	12.01	.31
Indian Territory No. 2 C, Hartshorne (lump):										
Mine sample	1071	1.46	6.40	1.38	1.38	7.03	1.48	.....	.....	.....
Do	1073	1.30	7.65	1.58						
Car sample	3406	2.81	8.75	1.82	2.81	8.75	1.82	1.43	1.72	.34
Kansas No. 6, Jewett (lump):										
Mine sample	2790	11.13	12.60	2.41	10.62	12.70	2.53	1.58	.....	.....
Do	2791	10.12	12.81	2.66						
Car sample	2843	9.04	15.72	3.72	9.04	15.72	3.72	.....	3.02	1.19
Kentucky No. 1 B, Straight Creek (lump):										
Mine sample	2350	3.42	3.18	1.53	3.34	3.06	1.22	.73	.....	.34
Do	2351	3.25	2.93	.91						
Car sample	2517	2.61	3.37	.88	2.61	3.37	.88	.....	.31	.....

TABLE 2.—*Classification of impurities in mine and car samples of screened coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Kentucky No. 1 C, Straight Creek (nut):										
Mine sample	2350	3.42	3.18	1.53	3.34	3.05	1.22	.....	.....	.10
Do	2351	3.25	2.93	.91						
Car sample	2445	5.21	8.22	1.12	5.21	8.22	1.12	1.87	5.17	.....
Kentucky No. 7, Central City (lump and egg):										
Mine sample	2453	8.76	9.42	4.07	8.75	10.09	3.88	.28	.61	.28
Do	2454	8.75	10.77	3.69						
Car sample	2595	8.47	9.48	3.60	8.47	9.48	3.60	.....	.....	.....
Kentucky No. 9 A, McHenry (nut):										
Mine sample	3722	10.03	7.67	2.56	9.96	8.18	2.50	1.26	.....	.....
Do	3723	9.89	8.69	2.45						
Car sample	3865	8.70	8.96	3.14	8.70	8.96	3.14	.....	.78	.64
Missouri No. 6, Huntsville (lump):										
Mine sample	2817	14.01	10.29	5.23	12.69	9.37	4.40	.....	.....	.....
Do	2818	11.38	8.45	3.57						
Car sample	2904	13.80	11.74	5.60	13.80	11.74	5.60	1.11	2.37	1.20
Missouri No. 7 A, Nouinger (nut):										
Mine sample	2823	17.19	9.28	2.76	16.69	10.98	2.89	.33	.....	.....
Do	2824	16.19	12.69	3.03						
Car sample	2936	16.36	19.51	3.53	16.36	19.51	3.53	.....	8.53	.64
Missouri No. 7 B, Nouinger (nut):										
Mine sample	2823	17.19	9.28	2.76	16.69	10.98	2.89	.30	.....	.....
Do	2824	16.19	12.69	3.03						
Car sample	2937	16.39	20.18	3.12	16.39	20.18	3.12	.....	9.20	.23
Missouri No. 7 C, Nouinger (screenings):										
Mine sample	2823	17.19	9.28	2.76	16.69	10.98	2.89	.....	.....	.....
Do	2824	16.19	12.69	3.03						
Car sample	2942	17.30	23.38	2.94	17.30	23.38	2.94	.61	12.40	.05
New Mexico No. 3 C, Van Houten (lump):										
Mine sample	3221	2.50	9.13	.72	2.99	11.02	.68	.24	.....	.04
Do	3222	3.48	12.92	.64						
Car sample	3308	2.75	15.52	.64	2.75	15.52	.64	.....	4.50	.....
New Mexico No. 4 B, Brilliant (screenings):										
Mine sample	3228	2.19	11.11	.57	2.43	10.46	.57	.....	.....	.....
Do	3229	2.67	9.82	.58						
Car sample	33[illegible]	3.38	13.54	.61	3.38	13.54	.61	.95	3.08	.04
Ohio No. 4, Bradley (lump):										
Mine sample	[illegible]	4.06	7.75	3.67	4.13	7.63	3.44	.60	.....	.....
Do	19[illegible]	4.20	7.51	3.22						
Car sample	2083	3.53	9.12	3.47	3.53	9.12	3.47	.....	1.49	.03
Ohio No. 5, Rush Run (lump):										
Mine sample	1944	4.69	6.01	1.54	4.84	5.85	1.24	.50	.....	.....
Do	1945	4.99	5.70	.95						
Car sample	2062	4.34	7.30	1.72	4.34	7.30	1.72	.....	1.45	.48
Ohio No. 7, Danford (lump):										
Mine sample	2090	6.28	7.30	3.55	6.04	6.94	3.08	.....	.....	.....
Do	2091	5.80	6.58	2.62						
Car sample	2656	6.65	10.55	3.13	6.65	10.55	3.13	.61	3.61	.05
Ohio No. 9 A, Clarion (lump):										
Mine sample	2208	6.79	7.66	3.34	7.08	6.91	3.05	1.49	.....	.....
Do	2209	7.38	6.16	2.77						
Car sample	2310	5.59	8.29	3.15	5.59	8.29	3.15	.....	1.38	.10
Ohio No. 9 B, Clarion (screenings):										
Mine sample	2208	6.79	7.66	3.34	7.08	6.91	3.05	.....	.....	.....
Do	2209	7.38	6.16	2.77						
Car sample	2311	8.10	11.93	3.35	8.10	11.93	3.35	1.02	5.02	.30
Ohio No. 10, Mineral City (lump):										
Mine sample	3968	5.61	8.72	2.89	5.03	8.63	3.31	.54	1.10	.38
Do	3969	4.46	8.54	3.73						
Car sample	4059	4.49	7.53	2.93	4.49	7.53	2.93	.....	.....	.....
Ohio No. 11, Flushing (lump):										
Mine sample	3985	3.96	9.04	4.25	4.05	8.50	4.18	.61	.....	.....
Do	3986	4.13	7.96	4.12						
Car sample	4157	3.44	12.94	4.32	3.44	12.94	4.32	.....	4.44	.14
Pennsylvania No. 4, Greensburg (lump):										
Mine sample	1942	2.73	9.13	1.33	2.76	8.60	1.08	.....	.....	.....
Do	1943	2.80	8.07	.83						
Car sample	2187	3.15	10.41	1.26	3.15	10.41	1.26	.39	1.81	.18
Pennsylvania No. 5, Ellsworth (lump):										
Mine sample	1966	3.01	4.83	.73	2.96	5.11	.90	.50	.....	.02
Do	1967	2.91	5.40	1.08						
Car sample	2068	2.46	6.05	.88	2.46	6.05	.88	.....	.94	.....

TABLE 2.—*Classification of impurities in mine and car samples of screened coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Pennsylvania No. 10, Bruce (lump):										
Mine sample	2080	3.67	5.46	1.37	3.87	5.39	1.34	1.26	.....	.08
Do	2081	4.08	5.32	1.31						
Car sample	2229	2.61	6.17	1.26	2.61	6.17	1.26	.....	.78	.....
Tennessee No. 9 A, Coalmont (lump):										
Mine sample	2995	3.44	9.21	.73	3.60	8.69	.71	.....	.....	.....
Do	2996	3.77	8.17	.68						
Car sample	3113	3.92	14.09	.94	3.92	14.09	.94	.32	5.40	.23
Texas No. 3, Olsen (lump):										
Mine sample	2562	36.01	7.38	.77	35.78	7.71	.76	4.72	.....	.....
Do	2563	35.56	8.04	.75						
Car sample	2734	31.06	7.88	.99	31.06	7.88	.99	.....	.17	.23
Virginia No. 3, Toms Creek (lump):										
Mine sample	2281	2.70	4.49	.52	2.80	4.31	.53	.....	.....	.....
Do	2282	2.91	4.13	.55						
Car sample	2382	3.05	4.48	.67	3.05	4.48	.67	.25	.17	.14
Virginia No. 4, Darby (lump):										
Mine sample	2323	3.89	3.06	.34	3.72	2.78	.42	.....	.....	.....
Do	2324	3.55	2.51	.50						
Car sample	2358	4.35	4.33	.79	4.35	4.33	.79	.63	1.55	.37
West Virginia No. 16 A, Monongah (lump):										
Mine sample	2041	2.89	5.71	.69	2.78	5.64	.87	.....	.....	.....
Do	2042	2.68	5.57	1.06						
Car sample	2808	4.12	8.00	1.17	4.12	8.00	1.17	1.34	2.36	.30
West Virginia No. 22 A, Hernshaw (nut):										
Mine sample	3456	2.75	5.49	.63	3.12	5.96	.63	.....	.....	.....
Do	3457	3.49	6.44	.63						
Car sample	3711	4.59	9.80	1.01	4.59	9.80	1.01	1.47	3.84	.38
West Virginia No. 23 B, Monarch (nut):										
Mine sample	3458	3.13	3.54	.59	3.65	4.92	.91	.40	.....	.....
Do	3459	4.17	6.30	1.24						
Car sample	3625	3.25	7.58	1.22	3.25	7.58	1.22	.....	2.66	.31
West Virginia No. 25, Charleston (lump):										
Mine sample	4290	3.46	8.20	.58	[illegible]8	7.49	.61	.....	.27	.....
Do	4291	3.91	6.78	.64						
Car sample	4360	4.21	7.22	.64	[illegible]21	7.22	.64	.53	.....	.03
Average, mine samples	.....	.....	.....	.....	9.41	8.14	2.32	1.19	.50	.31
Average, car samples	.....	.....	.....	.....	9.17	11.20	2.57	1.26	3.42	.42
Number of mine samples	.....	.....	.....	.....	67	67	67	41	6	16
Number of car samples	.....	.....	.....	.....	67	67	67	26	61	51

TABLE 3.—*Classification of impurities in mine and car samples of slack coal.*

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Arkansas No. 1 B, Huntington:										
Mine sample	2585	3.53	7.77	1.29	3.76	7.45	1.30	.....	.....	0.24
Do	2586	4.00	7.14	1.32						
Car sample	2689	7.49	17.97	1.06	7.49	17.97	1.06	3.73	10.52	.....
Arkansas No. 9, Bonanza:										
Mine sample	2599	1.99	7.06	1.05	2.05	6.88	1.41	.....	.....	.41
Do	2600	2.12	6.70	1.78						
Car sample	2690	5.26	24.81	1.00	5.26	24.81	1.00	3.21	17.93	.....
Illinois No. 7 C, Collinsville:										
Mine sample	1608	12.27	11.35	4.66	12.07	11.46	4.70	1.53	.....	.52
Do	1609	11.87	11.58	4.75						
Car sample	.....	10.54	25.30	4.18	10.54	25.30	4.18	.....	13.84	.....
Illinois No. 9 C, Staunton:										
Mine sample	1625	13.29	8.90	4.12	14.28	9.05	3.91	.....	.....	.10
Do	1626	15.27	9.20	3.70						
Car sample	4247	15.25	15.35	3.81	15.25	15.35	3.81	.97	6.30	.....
Indiana No. 18 A, Winslow:										
Mine sample	3525	12.88	6.14	1.70	13.35	6.08	1.55	.....	.....	.07
Do	3526	13.83	6.02	1.41						
Car sample	3747	15.09	7.43	1.48	15.09	7.43	1.48	1.74	1.35	.....

TABLE 3.—*Classification of impurities in mine and car samples of slack coal*—Con.

Description of sample.	Laboratory No.	Percentage of impurities.			Average.			Excess.		
		Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.	Moisture.	Ash.	Sulphur.
Indian Territory No. 2 B, Hartshorne:										
Mine sample	1071	1.46	6.40	1.38	1.38	7.02	1.48	.....	.....	.....
Do	1073	1.30	7.65	1.58						
Car sample	3405	6.27	14.29	1.79	6.27	14.29	1.79	4.89	7.27	.31
Kansas No. 2 B, Yale:										
Mine sample	1017	2.44	10.60	5.63	2.40	11.19	5.75	.....	.....	1.05
Do	1019	2.36	11.79	5.88						
Car sample	4361	8.01	20.38	4.70	8.01	20.38	4.70	5.61	9.19	.....
Missouri No. 10, Bevier:										
Mine sample	4196	15.26	8.70	4.37	15.33	10.15	4.07	.10	.....	.38
Do	4197	15.41	11.61	3.78						
Car sample	4257	15.23	20.50	3.69	15.23	20.50	3.69	.....	10.35	.....
New Mexico No. 3 B, Van Houten:										
Mine sample	3221	2.50	9.13	.72	2.99	11.02	.68	.....	.....	.....
Do	3222	3.48	12.92	.64						
Car sample	3307	4.36	15.92	.83	4.36	15.92	.83	1.37	4.90	.15
Tennessee No. 7 B, Wilder:										
Mine sample	2979	3.46	9.08	2.42	3.25	9.60	3.13	.....	.....	1.04
Do	2980	3.04	10.13	3.84						
Car sample	3425	3.37	10.06	2.09	3.37	10.06	2.09	.12	.46	.....
Tennessee No. 9 B, Coalmont:										
Mine sample	2995	3.44	9.21	.73	3.60	8.69	.70	.....	.....	.....
Do	2996	3.77	8.17	.68						
Car sample	3114	5.68	18.55	.74	5.68	8.55	.74	.....	.....	.....
Do	.....	.....	.....	.....	.....	.....	.....	2.08	9.86	.04
Utah No. 2, Coalville:										
Mine sample	3200	14.07	6.26	1.28	13.96	5.76	1.30	1.30	.....	.....
Do	3201	13.86	5.26	1.32						
Car sample	3259	12.66	5.85	1.39	12.66	5.85	1.39	.....	.09	.09
Virginia No. 5 A, Blacksburg:										
Mine sample	4092	3.51	17.64	.84	3.24	19.79	.76	.....	1.76	.13
Do	4093	2.98	21.94	.68						
Car sample	4287	4.80	18.03	.63	4.80	18.03	.63	1.56	.....	.....
Virginia No. 5 B, Blacksburg:										
Mine sample	4092	3.51	17.64	.84	3.24	19.79	.76	.....	3.56	.11
Do	4093	2.98	21.94	.68						
Car sample	4294	7.52	16.23	.65	7.52	16.23	.65	4.28	.....	.....
West Virginia No. 16 B, Monongah:										
Mine sample	2041	2.89	5.71	.69	2.78	5.64	.87	.....	.....	.....
Do	2042	2.68	5.57	1.06						
Car sample	2264	5.57	8.37	1.20	5.57	8.37	1.20	2.79	2.73	.33
Average, mine samples	.....	.....	.....	.....	6.51	9.97	2.16	.98	2.66	.41
Average, car samples	.....	.....	.....	.....	8.47	15.94	1.95	2.70	7.29	.18
Number of mine samples	.....	.....	.....	.....	15	15	15	3	2	10
Number of car samples	.....	.....	.....	.....	15	15	15	12	13	5

MOISTURE.

MOISTURE IN RUN-OF-MINE COAL.

An examination of Table 1 shows a slight excess of moisture in the general average of the mine samples over that of the car samples, these averages being 8.01 and 7.92, respectively. In the entire lot of 87 coals sampled, 36, or 41.4 per cent, show an excess of moisture in the car samples, and 50, or 57.5 per cent, show an excess in the mine samples. One coal, equal to 1.1 per cent of the whole, showed an equal amount of moisture in the average mine and car samples. This coal is West Virginia No. 13, one of the low-moisture coals of the Kanawha River district. The equality in moisture content of both kinds of samples is of course purely accidental. Of the 50 samples collected during the exposition, 26, or 52 per cent, showed an excess of moisture in the car samples, and 24, or 48 per cent, showed an

excess in the mine samples. On comparing the results of both periods, it is seen that in the exposition work the results very nearly balance, a slight majority of the car samples containing a greater amount of moisture than the mine samples. In the sampling work which followed, when the mine samples were being pulverized in the mine, this condition was reversed, more moisture being found in the mine samples than in the car samples.

A further examination of the table of run-of-mine samples shows that the greatest excess of moisture found in the car samples was 3.37 per cent, in Tennessee No. 5; that 0.02 per cent, in Wyoming No. 2 B, represented the smallest excess; and that the average excess for the whole was 1.17 per cent. The average for the work done in 1904 was 1.35 per cent, showing that there has been some improvement in reducing the excess of moisture in the car sample over that in the mine sample.

The greatest excess of moisture in the mine samples is in North Dakota No. 3, which shows 5.24 per cent more in the average mine sample than in the car sample. The smallest difference, 0.07 per cent, is in West Virginia No. 21. The average, 1.01 per cent for the entire lot of mine samples containing more moisture than the car samples, is practically the same as the average of 1.11 per cent obtained in 1904.

In order to compare these results further and arrive at a definite coefficient for correcting the moisture of the mine samples, the results have been arranged in two tables according to the actual amount of moisture contained in the average mine samples. Table 4 is made up of samples having a moisture content of less than 5 per cent; Table 5 comprises those having a moisture content of more than 5 per cent.

Of the 87 coals sampled as run-of-mine coal five (Arkansas No. 10, California No. 1, North Dakota No. 3, Texas No. 4, and Wyoming No. 6) are lignites and on account of the high moisture content, affecting the whole analysis, have been omitted from the tables.

TABLE 4.—*Coals containing less than 5 per cent of moisture in the average mine samples, exclusive of lignites.*

Coal.	Average per cent of moisture in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Alabama No. 2 B	4.61	3.95	0.66	.....
Alabama No. 3	3.14	2.72	.42	.....
Alabama No. 4	3.63	6.43	.....	2.80
Alabama No. 5	3.82	5.59	.....	1.77
Alabama No. 6	3.02	3.39	.....	.37
Kentucky No. 5	4.49	4.36	.13	.....
Maryland No. 1	2.96	2.33	.63	.....
Maryland No. 2	2.50	3.42	.....	.92
New Mexico No. 3 A	2.98	3.45	.....	.47
New Mexico No. 4 A	2.43	2.78	.....	.35
New Mexico No. 5	2.28	2.72	.....	.44
Ohio No. 6	4.02	5.31	.....	1.29
Ohio No. 12	3.21	3.55	.....	.34
Pennsylvania No. 6	3.44	3.35	.09	.....

TABLE 4.—*Coals containing less than 5 per cent of moisture in the average mine samples, exclusive of lignites*—Continued.

Coal.	Average per cent of moisture in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Pennsylvania No. 7	3.04	4.09	.....	1.05
Pennsylvania No. 8	3.29	3.51	.....	.22
Pennsylvania No. 9	3.26	3.09	.17	.....
Pennsylvania No. 11	2.53	1.95	.58	.....
Pennsylvania No. 12	2.90	1.96	.94	.....
Pennsylvania No. 13	2.73	2.65	.08	.....
Pennsylvania No. 15	3.33	2.85	.48	.....
Pennsylvania No. 16	2.80	4.25	.....	1.45
Pennsylvania No. 17	2.22	4.35	.....	2.13
Pennsylvania No. 18	2.54	4.46	.....	1.92
Pennsylvania No. 19	2.41	3.39	.....	.98
Pennsylvania No. 20	2.64	4.00	.....	1.36
Pennsylvania No. 21	2.61	5.13	.....	2.52
Tennessee No. 1	3.68	4.81	.....	1.13
Tennessee No. 2	3.40	5.09	.....	1.69
Tennessee No. 3	4.33	5.38	.....	1.05
Tennessee No. 4	3.18	6.39	.....	3.21
Tennessee No. 5	2.22	5.59	.....	3.37
Tennessee No. 6	3.40	3.89	.....	.49
Tennessee No. 7A	3.25	3.03	.22	.....
Tennessee No. 8	3.12	2.87	.25	.....
Virginia No. 6	2.81	5.62	.....	2.81
West Virginia No. 4 B	3.52	3.91	.....	.39
West Virginia No. 13	3.74	3.74	.....	.....
West Virginia No. 14	3.53	5.09	.....	1.56
West Virginia No. 15	3.03	2.01	1.02	.....
West Virginia No. 17	3.63	3.46	.17	.....
West Virginia No. 18	3.42	2.86	.56	.....
West Virginia No. 19	3.38	2.96	.42	.....
West Virginia No. 20	2.75	2.85	.....	.10
West Virginia No. 21	3.64	3.57	.07	.....
West Virginia No. 22 B	3.12	3.42	.....	.30
West Virginia No. 23 A	3.65	2.05	1.60	.....
Average	3.18	3.78	.47	1.30
Number of samples	47	47	18	28

Table 4 comprises 47 coals having a moisture content of less than 5 per cent in the average mine samples. Of these 47 coals, 18, or 38 per cent, show an excess in the mine samples, and 28, or 60 per cent, show an excess in the car samples. In one sample the moisture is equal in both car and mine samples. Comparing this table with the general table of run-of-mine samples (Table 1), we see that conditions are reversed, and that the conclusions drawn from the general table do not apply to these selected samples. In the general table the average excess in the mine samples is 1.01 per cent, as compared to 0.47 per cent in the coals having less than 5 per cent of moisture in the mine samples. In the general table the average excess in the car samples is 1.17 per cent, as compared to 1.30 per cent in Table 4. The average moisture in the mine samples containing less than 5 per cent is 3.18 per cent, and the average in the corresponding car samples is 3.78 per cent. If we divide the average in the car samples by the average in the mine samples we get a coefficient for correcting the moisture in mine samples containing less than 5 per cent to approximately the moisture that might be expected in commercial run-of-mine coal. This result is $3.78 \div 3.18 = 1.19$. It will, however, be safe to use this coefficient only when the coal is dry, and when it

is certain that no great amount of moisture has been added from outside sources, such as wet places in the mine, rain, etc.

The coals which do not appear in Table 4—that is, those containing more than 5 per cent of moisture in the average mine sample—have been arranged in Table 5.

TABLE 5.—*Coals containing more than 5 per cent of moisture in the average mine samples, exclusive of lignites.*

Coal.	Average per cent of moisture in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples
Illinois No. 6 B	12.90	11.93	0.97	.....
Illinois No. 7 D	12.07	10.86	1.21	.....
Illinois No. 9 A	14.28	13.54	.74	.....
Illinois No. 11 B	8.30	8.86	.....	0.56
Illinois No. 12	8.35	8.20	.15	.....
Illinois No. 19 C	10.03	9.58	.45	.....
Illinois No. 25 A	11.89	11.35	.54	.....
Illinois No. 26	15.14	15.68	.....	.54
Illinois No. 27	14.23	16.00	.....	1.77
Illinois No. 29 B	13.47	12.47	1.00	.....
Illinois No. 34 B	7.53	7.81	.....	.28
Indiana No. 5	12.15	12.03	.12	.....
Indiana No. 6	9.83	10.80	.....	.97
Indiana No. 9 B	14.03	13.53	.50	.....
Indiana No. 12	11.19	10.57	.62	.....
Indiana No. 13	13.65	12.79	.86	.....
Indiana No. 14	12.54	7.88	4.66	.....
Indiana No. 15	13.75	13.58	.17	.....
Indiana No. 16	10.85	10.30	.55	.....
Indiana No. 17	11.23	12.08	.....	.85
Kentucky No. 6	6.73	5.12	1.61	.....
Kentucky No. 8	7.77	5.46	2.31	.....
Kentucky No. 9 B	9.96	8.04	1.92	.....
Missouri No. 5	13.63	12.92	.71	.....
Ohio No. 1	7.97	7.71	.26	.....
Ohio No. 2	9.16	9.01	.15	.....
Ohio No. 3	10.27	9.90	.37	.....
Ohio No. 8	8.89	7.55	1.34	.....
Virginia No. 1	5.65	4.35	1.30	.....
Virginia No. 2	5.35	3.35	2.00	.....
Washington No. 1	17.07	14.30	2.77	.....
Wyoming No. 2 B	8.91	8.93	.....	.02
Wyoming No. 3	18.08	15.12	2.96	.....
Wyoming No. 4	12.05	11.30	.75	.....
Wyoming No. 5	12.75	11.64	1.11	.....
Average	11.19	10.42	1.15	.71
Number of samples	35	35	28	7

The 35 coals listed in Table 5 contain from 5.35 per cent moisture in Virginia No. 2 to 18.08 per cent in Wyoming No. 3. Of these, 28, or 80 per cent, contain more moisture in the mine samples than in the car samples, and 7, or 20 per cent, contain more moisture in the car samples than in the mine samples. The average excess in the mine samples is 1.15 and the average excess in the car samples is 0.71. The average moisture in the mine samples is 11.19 per cent and in the car samples 10.42 per cent. The coefficient for correcting the moisture in mine samples containing more than 5 per cent so that they will represent commercial run-of-mine coal is $10.42 \div 11.19 = 0.93$. In other words, when coals containing more than 5 per cent of moisture are sampled in the mine by the prescribed method, the moisture to be

expected in commercial run-of-mine coal can be found by multiplying the moisture content of the sample as determined by analysis by 0.93.

MOISTURE IN SCREENED COAL.

Table 2 gives a complete list of samples of screened coal received at the fuel-testing plant. By screened coal is meant all coal that has been sized at the mine, and is neither run-of-mine nor slack nor fine coal. This includes lump, nut, egg, and various special sizes, as Nos. 1, 2, 3, etc. There are 67 of these coals on which to base conclusions; 41 show an excess of moisture in the mine samples, and 26 an excess in the car samples. Expressing these figures in percentages, we find 38.8 per cent of the coals with an excess in the car samples, and 61.2 per cent with an excess in the mine samples. The moisture in the mine sample ranges from 35.78 per cent in a Texas lignite down to 1.38 per cent in Indian Territory No. 2; the moisture in the car samples ranges from 31.06 per cent in the same Texas lignite down to 2.46 per cent in Pennsylvania No. 5. The average moisture in all the mine samples in the table is 9.41 per cent, and the average in the car samples is 9.17 per cent. The average excess in the mine samples is 1.19 per cent, and the average excess in the car samples is 1.26 per cent. These figures very nearly balance, so that from the evidence at hand the moisture in mine samples can be considered to represent that in commercial screened coal. For the reason that a more compact mass is found in a carload of the smaller sized coal, it is not safe to predict the moisture from the mine sample for sizes below nut coal. The actual coefficient for determining the moisture in screened coal from the moisture found in mine samples is $9.17 \div 9.41 = 0.97$.

MOISTURE IN SLACK COAL.

The results on slack coal from 15 mines are shown in Table 3. The data are not sufficient to draw final conclusions, but the comparisons are made here as a matter of interest. Of these 15 coals, 12 show an excess of moisture in the car samples and 3 show an excess in the mine samples. The average moisture for all the mine samples is 6.51 per cent, and the average for the car samples is 8.47 per cent. From these figures we get the following coefficient: $8.47 \div 6.51 = 1.30$.

CONCLUSIONS.

Summing up the data on moisture, we find that when the run-of-mine coals as shown in Table 1 are subdivided into two classes (Tables 4 and 5), consisting of coals containing less than 5 per cent of moisture and coals containing more than 5 per cent, the following results are obtained:

Run-of-mine coal containing less than 5 per cent of moisture will under normal conditions gain some moisture when exposed to the

weather, and if the moisture in any mine sample taken by the method described above and containing less than 5 per cent be multiplied by the coefficient 1.19 the probable amount of moisture in commercial run-of-mine coal will be found. The coefficient for this same class of coal based on the previous sampling was 1.47; this figure is less specific than the new one, however, as it was based on other grades of coal as well as run-of-mine, and should therefore be discarded.

The coals containing more than 5 per cent of moisture in the average mine sample show a decided loss of moisture in the car samples. The coefficient for this class of coal is 0.93. Therefore to determine the amount of moisture in run-of-mine coal containing more than 5 per cent of moisture in the mine sample, multiply the percentage of moisture in the mine sample by 0.93. The coefficient for such coal based on the previous work was 0.72, which should be discarded for the new figure, as it was based on various grades of coal and not entirely on run-of-mine. A prominent feature noted in comparing these two classes of coals is that there seems to be a tendency on the part of the high-moisture coals and the low-moisture coals to approach a common limit very near 5 per cent. This is shown by the fact that the average loss in the car samples of coal with an original moisture content of more than 5 per cent was 1.15 per cent, and the average gain in moisture in the coals with an original moisture content of less than 5 per cent was 1.30 per cent, the gains and losses very nearly balancing.

On reviewing the figures obtained for screened coal it is seen that, as would be expected, the screened coal will tend to lose moisture when exposed under normal conditions. The coefficient for determining the amount of moisture that may be expected in the commercial product is 0.97, and therefore multiplying the moisture in the mine sample by 0.97 will give the moisture in commercial coal.

The figures obtained in reference to slack coal are probably not based on sufficient evidence to draw final conclusions, but slack is generally rather wet, as it receives any water that drains from the other sizes of coal while being screened. It is certain that under normal conditions slack coal contains a larger amount of moisture than mine samples, but from the evidence brought out in the results on high-moisture run-of-mine coal the slack is likely to lose some of the moisture added in screening, and consequently will vary greatly under varying conditions. The coefficient obtained is 1.30, but, as stated, it is based on too meager data to be reliable.

Finally, it appears from all the evidence that moisture is an extremely irregular constituent of coal. For this reason, in taking mine samples great care should be exercised to select a dry place in the mine for cutting the sample and to prevent an excessive amount of

moisture from getting into the coal in the form of water by the drip from the roof of the mine or by contact with the sample on the floor. It is of the utmost importance to crush the sample in the atmosphere of the mine, or where it has been impossible to procure a dry sample, to dry the coal before crushing until all signs of visible moisture have been removed. More important than anything else in this connection is the manner in which the sample is packed for the laboratory. The sample should be sealed in an air-tight glass jar, bottle, or can. To illustrate the importance of this precaution, duplicate samples containing 9 per cent of moisture were sent to the chemical laboratory, one in the regulation can provided by the fuel-testing plant, and the other in a canvas sack such as is ordinarily used for this purpose. The samples were analyzed at the same time, and the moisture in the sample that had been kept in the sack for less than a week was approximately 3 per cent less than in the sample from the can. Another sample was weighed in a can and then sent by mail from St. Louis to Washington and back. It was again weighed and the result showed that samples sealed in an air-tight receptacle do not undergo any loss in weight.

SULPHUR.

Sulphur plays an important part in sampling only when it occurs in bands or other consolidated masses, generally in the form of pyrites. In most coals the percentage is comparatively small. The following results show what may be expected when samples are taken by the method recommended in this paper:

SULPHUR IN RUN-OF-MINE COAL.

Of the 87 coals included in Table 1, 28 show an excess in the mine samples and 59 an excess in the car samples. The average sulphur content of the mine samples is 2.04 per cent, and the average for the car samples is 2.16 per cent. From these figures we get $2.16 \div 2.04 = 1.06$, the coefficient of increase. For the work of 1904 this coefficient was 1.04, and Mr. Campbell, in studying the results of sampling for 1904 and 1905, combined the two and found the sulphur coefficient to be the same as the one just determined—1.06. In order to obtain a more definite coefficient, however, the sulphur items for 82 coals in Table 1 have been divided into two classes, as shown in Table 6, comprising the coals containing less than 3 per cent of sulphur in the average mine sample, and Table 7, comprising the coals containing more than 3 per cent.

TABLE 6.—*Coals containing less than 3 per cent of sulphur in the average mine samples.*

Coal.	Average per cent of sulphur in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Alabama No. 2 B	1.40	1.12	0.28	.....
Alabama No. 3	.51	.55	.....	0.04
Alabama No. 4	1.36	1.08	.28	.....
Alabama No. 5	.74	1.40	.....	.66
Alabama No. 6	.58	.59	.....	.01
Illinois No. 11 B	2.82	2.46	.36	.....
Illinois No. 19 C	.47	.52	.....	.05
Illinois No. 34 B	1.57	2.36	.....	.79
Indiana No. 9 B	2.85	3.15	.....	.30
Indiana No. 13	2.71	3.18	.....	.47
Indiana No. 15	.95	.91	.04	.....
Kentucky No. 5	.52	.67	.....	.15
Kentucky No. 6	.46	.57	.....	.11
Kentucky No. 8	1.02	1.18	.....	.16
Kentucky No. 9 B	2.50	2.97	.....	.47
Maryland No. 1	1.41	1.49	.....	.08
Maryland No. 2	.83	.84	.....	.01
New Mexico No. 3 A	.68	.73	.....	.05
New Mexico No. 4 A	.57	.61	.....	.04
New Mexico No. 5	.70	.69	.01	.....
Ohio No. 3	1.27	1.81	.....	.54
Ohio No. 8	2.37	2.84	.....	.47
Pennsylvania No. 6	1.82	1.94	.....	.12
Pennsylvania No. 7	1.83	2.08	.....	.25
Pennsylvania No. 8	1.06	.94	.12	.....
Pennsylvania No. 9	1.90	2.04	.....	.14
Pennsylvania No. 11	1.70	1.18	.52	.....
Pennsylvania No. 12	1.20	2.19	.....	.99
Pennsylvania No. 13	2.04	2.16	.....	.12
Pennsylvania No. 16	1.46	1.59	.....	.13
Pennsylvania No. 17	1.46	1.51	.....	.05
Pennsylvania No. 18	2.15	1.49	.66	.....
Pennsylvania No. 19	1.19	1.05	.14	.....
Pennsylvania No. 20	2.66	2.85	.....	.19
Pennsylvania No. 21	1.09	.86	.23	.....
Tennessee No. 1	1.13	1.58	.....	.45
Tennessee No. 2	.85	.98	.....	.13
Tennessee No. 3	.86	.99	.....	.13
Tennessee No. 4	.85	.98	.....	.13
Tennessee No. 6	.93	.78	.15	.....
Virginia No. 1	1.89	1.15	.74	.....
Virginia No. 2	.79	.92	.....	.13
Virginia No. 6	1.52	1.21	.31	.....
Washington No. 1	.44	.72	.....	.28
West Virginia No. 4 B	.82	1.07	.....	.25
West Virginia No. 13	1.14	.89	.25	.....
West Virginia No. 14	.92	1.03	.....	.11
West Virginia No. 15	2.40	2.54	.....	.14
West Virginia No. 17	1.44	1.45	.....	.01
West Virginia No. 18	.65	.67	.....	.02
West Virginia No. 19	.65	.89	.....	.24
West Virginia No. 20	1.24	1.44	.....	.20
West Virginia No. 21	1.15	1.32	.....	.17
West Virginia No. 22 B	.63	.83	.....	.20
West Virginia No. 23 A	.91	1.35	.....	.44
Wyoming No. 4	.29	.28	.01	.....
Wyoming No. 5	.92	.81	.11	.....
Average	1.27	1.36	.26	.23
Number of samples	57	57	16	41

Of the coals containing less than 3 per cent of sulphur in the average mine samples, 41 show an excess in the car sample and 16 show an excess in the mine sample, the average excess being 0.23 per cent and 0.26 per cent, respectively. The average amount of sulphur contained in the mine samples is 1.27 per cent, and the corresponding average in the car samples is 1.36 per cent. These figures show that no great difference exists between the mine samples and the car samples as regards their sulphur content. The coefficient for this class of coals is $1.36 \div 1.27 = 1.07$.

TABLE 7.—*Coals containing more than 3 per cent of sulphur in the average mine samples.*

Coal.	Average per cent of sulphur in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Illinois No. 6 B	3.78	4.29	.....	0.51
Illinois No. 7 D	4.70	4.53	0.17	.....
Illinois No. 9 A	3.91	4.03	.....	.12
Illinois No. 12	3.22	3.48	.....	.26
Illinois No. 25 A	3.71	4.76	.....	1.05
Illinois No. 26	3.80	3.51	.29	.....
Illinois No. 27	4.38	4.05	.33	.....
Illinois No. 29 B	3.67	4.37	.....	.70
Indiana No. 5	4.10	4.27	.....	.17
Indiana No. 6	3.99	4.39	.....	.40
Indiana No. 12	3.47	3.87	.....	.40
Indiana No. 14	4.36	5.14	.....	.78
Indiana No. 16	3.66	4.23	.....	.57
Indiana No. 17	3.87	3.65	.22	.....
Missouri No. 5	4.33	5.03	.....	.70
Ohio No. 1	4.27	4.61	.....	.34
Ohio No. 2	4.24	4.02	.22	.....
Ohio No. 6	3.42	3.33	.09	.....
Ohio No. 12	3.48	3.80	.....	.32
Pennsylvania No. 15	3.84	3.87	.....	.03
Tennessee No. 5	3.40	3.23	.17	.....
Tennessee No. 7 A	3.13	3.26	.....	.13
Tennessee No. 8	3.50	4.56	.....	1.06
Wyoming No. 2 B	4.63	4.03	.60	.....
Wyoming No. 3	6.88	6.66	.22	.....
Average	3.99	4.20	.26	.47
Number of samples	25	25	9	16

Table 7 comprises 25 coals containing more than 3 per cent of sulphur in the average mine sample. Nine of these show an excess in the mine sample and 16, nearly twice as many, show an excess in the car sample. The average sulphur contained in the mine samples is 3.99 per cent, and the average for the car samples is 4.20. The average excess in the mine samples is 0.26, and the average excess in the car samples 0.47 per cent. This would indicate that in dealing with coals having a high sulphur content the chances are in favor of the mine sample being taken with too great an amount of care in discarding sulphur partings. The coefficient for correcting the sulphur shown by the mine sample is $4.20 \div 3.99 = 1.05$.

SULPHUR IN SCREENED COAL.

Screened coal for sampling was obtained from 67 mines. Of these coals, 16, or 24 per cent, show an excess of sulphur in the mine samples, and 51, or 76 per cent, an excess in the car samples, the average excess being 0.31 and 0.42 per cent for the mine samples and car samples, respectively. This indicates that in screened coal the sulphur can be expected generally to show an increase in commercial coal over that in the mine sample. The increase is slight, however, the average sulphur in the car samples being 2.57 per cent, and the average sulphur in the mine samples being 2.32 per cent. From these averages we get the coefficient of increase, $2.57 \div 2.32 = 1.10$. Therefore, to determine the amount of sulphur that may be expected in commercial screened coal (lump, nut, etc.), multiply the amount shown in the mine sample by 1.10.

SULPHUR IN SLACK COAL.

As already noted, at only 15 mines were samples of slack coal obtained on which to base conclusions, and this number is manifestly insufficient. Of the 15 coals, however, 10, or approximately 67 per cent, show more sulphur in the mine samples than in the car samples; the balance, or about 33 per cent, show more sulphur in the car samples than in the mine samples. Most of the coals in this list are comparatively low in sulphur, the smallest amount noted in the car samples being 0.63 per cent, and the maximum in the car samples 4.70 per cent. The average for the car samples is 1.95 per cent, and for the mine samples 2.16 per cent. The average excess in the car samples is 0.18 per cent, and in the mine samples 0.41 per cent. The correction coefficient obtained from the averages is $1.95 \div 2.16 = 0.90$.

CONCLUSIONS.

The differences in sulphur between mine samples and commercial coal will in most cases be slight, provided too much care is not used in excluding sulphur in partings and concretions from the sample. In the above results the sulphur in the run-of-mine samples very nearly balances, the correction coefficient being 1.07 for the coals showing less than 3 per cent of sulphur in the mine samples and 1.06 for those containing more than 3 per cent. With the screened coal, the actual results show more sulphur than in the run-of-mine coal, but the differences between mine samples and car samples remain slight, the coefficient determined being 1.10. Of course, the sulphur content in coal of this class will vary slightly, depending on the grade of coal and the size of the screen through which it is passed, as well as the form in which the sulphur occurs. If the sulphur comes from the mine in large pieces of a uniform size, it will pass into the coal of corresponding size and the other grades will show less sulphur. On this account it will be difficult to predict the amount of sulphur that is likely to be found in any particular size.

Contrary to expectation, the slack-coal results show more sulphur in the mine samples than in the cars. This is to be accounted for by the fact that comparatively few samples were examined and by the low average sulphur content of the coals forming this group of samples. As with screened coal, the form in which the sulphur occurs will have a great deal to do with the amount to be found in slack coal, and the coefficient 0.90 is of value only in studying the results on this particular set of samples of slack coal.

ASH.

ASH IN RUN-OF-MINE COAL.

By far the most important impurity in coal affecting any method of sampling is the ash due to extraneous matter associated with the coal. The results of the systematic sampling of the inspectors of the

fuel-testing plant show that the variation in ash, while the greatest in amount, is the most constant. According to Table 1, 80 coals show an excess of ash in the car samples and 6 show an excess in the mine samples; in one coal the ash is equal in the average of the mine samples and the car sample. The maximum amount of ash noted in the car samples is 20.79 per cent and the minimum 2.76 per cent; the maximum for the mine samples is 21.43 per cent and the minimum 2.14 per cent. The average for the mine samples is 7.54 per cent and the average for the car samples 10.21 per cent. These figures indicate that the coal samples have a considerable range in their ash content, and on this account the run-of-mine samples, exclusive of lignites, have been divided into two classes, those containing less than 7 per cent of ash (Table 8) and those containing more than 7 per cent (Table 9).

TABLE 8.—*Coals containing less than 7 per cent of ash in the average mine samples.*

Coal.	Average per cent of ash in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Alabama No. 4	2.80	12.92	.....	10.12
Alabama No. 5	3.43	16.08	.....	12.65
Alabama No. 6	3.67	6.83	.....	3.16
Kentucky No. 5	2.66	3.70	.....	1.04
Kentucky No. 6	2.14	2.76	.....	.62
Kentucky No. 8	4.88	7.92	.....	3.04
Maryland No. 2	6.22	7.09	.....	.87
Ohio No. 3	6.07	11.58	.....	5.51
Ohio No. 8	4.92	8.37	.....	3.45
Ohio No. 12	6.40	9.67	.....	3.27
Pennsylvania No. 8	5.58	6.63	.....	1.05
Pennsylvania No. 11	6.14	7.29	.....	1.15
Pennsylvania No. 12	5.75	9.25	.....	3.50
Pennsylvania No. 19	6.29	8.36	.....	2.07
Tennessee No. 1	5.78	11.15	.....	5.37
Tennessee No. 2	2.89	6.81	.....	3.92
Tennessee No. 3	3.41	7.05	.....	3.64
Tennessee No. 4	6.41	9.53	.....	3.12
Tennessee No. 6	5.33	14.43	.....	9.10
Virginia No. 1	5.71	4.87	0.84	.....
Virginia No. 2	3.49	5.58	.....	2.09
Virginia No. 6	4.55	9.79	.....	5.24
West Virginia No. 4 B	5.69	10.11	.....	4.42
West Virginia No. 13	3.88	3.91	.....	.03
West Virginia No. 14	5.74	3.27	2.47	.....
West Virginia No. 15	5.64	8.55	.....	2.91
West Virginia No. 17	6.46	8.12	.....	1.66
West Virginia No. 18	5.83	5.83	.....	.....
West Virginia No. 19	2.50	5.01	.....	2.51
West Virginia No. 20	4.83	7.83	.....	3.00
West Virginia No. 21	3.87	4.85	.....	.98
West Virginia No. 22 B	5.96	7.82	.....	1.86
West Virginia No. 23 A	4.92	8.10	.....	3.18
Wyoming No. 4	5.13	7.31	.....	2.18
Wyoming No. 5	2.93	3.41	.....	.48
Average	4.80	7.77	1.65	3.35
Number of samples	35	35	2	32

Of the 82 coals considered, 35 contain less than 7 per cent of ash. Of these, 32 show an excess in the car sample and only 2 show an excess in the mine sample. In one of the coals showing an excess in the mine sample (Virginia No. 1) the excess was only 0.84 per cent and is unimportant so far as it affects the general results. This slight excess is probably due to the fact that the mine from which the sample

was taken was only a prospect and the place in the mine from which the sample was taken was too near the outcrop, the car sample being taken from cleaner coal farther in the mine. The other coal showing an excess of ash in the mine sample is West Virginia No. 14, the mine sample of which contained 2.47 per cent more ash than the car sample. In this mine the coal was taken out with the greatest care and this, coupled with the fact that the sampler secured too much ash in all of his sampling, probably accounts for the discrepancy.

The average ash in the mine samples included in Table 8 is 4.80 per cent and the average in the car samples is 7.77 per cent. Dividing 7.77 by 4.80 gives 1.618, the coefficient for multiplying the ash shown by a mine sample containing less than 7 per cent to determine the amount of ash that may be expected in the commercial run-of-mine coal.

TABLE 9.—*Coals containing more than 7 per cent of ash in the average mine samples.*

Coal.	Average per cent of ash in—		Excess in—	
	Mine samples.	Car samples.	Mine samples.	Car samples.
Alabama No. 2 B	9.54	14.59	.....	5.05
Alabama No. 3	11.44	14.36	.....	2.92
Illinois No. 6 B	11.08	14.18	.....	3.10
Illinois No. 7 D	11.46	13.18	.....	1.72
Illinois No. 9 A	9.05	10.74	.....	1.69
Illinois No. 11 B	9.26	11.66	.....	2.40
Illinois No. 12	11.35	12.95	.....	1.60
Illinois No. 19 C	7.13	11.00	.....	3.87
Illinois No. 25 A	8.97	13.40	.....	4.43
Illinois No. 26	12.41	12.09	0.32	.....
Illinois No. 27	9.02	13.77	.....	4.75
Illinois No. 29 B	9.10	12.56	.....	3.46
Illinois No. 34 B	7.31	8.38	.....	1.07
Indiana No. 5	9.06	10.88	.....	1.82
Indiana No. 6	10.37	12.62	.....	2.25
Indiana No. 9 B	8.56	10.76	.....	2.20
Indiana No. 12	7.69	11.65	.....	3.96
Indiana No. 13	8.01	12.09	.....	4.08
Indiana No. 14	8.90	14.20	.....	5.30
Indiana No. 15	7.32	8.15	.....	.83
Indiana No. 16	10.21	11.75	.....	1.54
Indiana No. 17	8.18	11.02	.....	2.84
Kentucky No. 9 B	8.18	10.05	.....	1.87
Maryland No. 1	10.20	13.13	.....	2.93
Missouri No. 5	10.72	13.62	.....	2.90
New Mexico No. 3 A	10.02	16.67	.....	6.65
New Mexico No. 4 A	10.46	14.57	.....	4.11
New Mexico No. 5	12.73	14.57	.....	1.84
Ohio No. 1	8.62	11.95	.....	3.33
Ohio No. 2	8.48	11.34	.....	2.86
Ohio No. 6	7.25	8.52	.....	1.27
Pennsylvania No. 6	9.06	12.76	.....	3.70
Pennsylvania No. 7	11.95	12.47	.....	.52
Pennsylvania No. 9	9.27	11.33	.....	2.06
Pennsylvania No. 13	8.25	13.16	.....	4.91
Pennsylvania No. 15	8.76	10.07	.....	1.31
Pennsylvania No. 16	7.01	7.87	.....	.86
Pennsylvania No. 17	7.81	11.90	.....	4.09
Pennsylvania No. 18	7.58	8.47	.....	.89
Pennsylvania No. 20	8.60	10.54	.....	1.94
Pennsylvania No. 21	7.29	8.71	.....	1.42
Tennessee No. 5	7.55	9.76	.....	2.21
Tennessee No. 7 A	9.60	12.85	.....	3.25
Tennessee No. 8	10.96	13.77	.....	2.81
Washington No. 1	8.32	11.37	.....	3.05
Wyoming No. 2 B	21.43	20.79	.64	.....
Wyoming No. 3	10.82	16.70	.....	5.88
Average	9.50	12.19	.48	2.83
Number of samples	47	47	2	45

Of 82 coals sampled as run-of-mine (see p. 489) 47 contain more than 7 per cent of ash in the average mine sample, 2 of which show an excess in the mine sample and 45 an excess in the car sample. The excess in the two mine samples referred to is insignificant (less than 1 per cent), so that on the whole these results confirm the statement that in this grade of coal mine samples contain less ash than commercial coal.

The average ash contained in the mine samples listed in Table 9 is 9.50 per cent and the average for the corresponding car samples is 12.19 per cent. From these averages we get 12.19÷9.50=1.283, the coefficient for coals containing more than 7 per cent of ash.

ASH IN SCREENED COAL.

An examination of Table 2 reveals the fact that of the 67 samples of screened coal 6 show an excess of ash in the mine sample and 61 an excess in the car sample. The excess in the mine samples is probably due to the character of the slate and other ash-forming impurities and to the kind and size of the screens employed in each case. The greatest amount of ash recorded for the car samples of screened coal is 23.38 per cent and the minimum for the car samples is 2.37 per cent. The greatest amount of ash noted in the mine samples is 12.70 per cent and the minimum 2.78 per cent. The average for the car samples is 11.20 per cent and the average for the mine samples 8.14 per cent. These averages give 11.20÷8.14=1.376 as the coefficient for this grade of coal.

ASH IN SLACK COAL.

Table 3 includes only 15 coals sampled as slack coal, of which 13 show a decided increase in ash in the car samples and 2 an excess in the mine samples. These two mine samples were taken from the same mine, which is working a bed of anthracite(?) coal near Blacksburg, Va. They were compared with prepared sizes of the coal, so the comparison can hardly be considered a fair one. The greatest amount of ash noted in the car samples is 25.30 per cent and the car sample showing the smallest amount of ash contains 5.85 per cent, the average being 15.94 per cent. Compared with the car samples are mine samples ranging from 5.64 per cent up to 19.79 per cent, the average being 9.97 per cent. Exclusive of the Virginia anthracite referred to above the averages are for the car samples 15.75 per cent and for the mine samples 8.46 per cent. Dividing 15.75 by 8.46 gives 1.861, the coefficient for slack coal.

CONCLUSIONS.

The results of the comparison of the ash in the mine samples with the ash in the car samples show the greatest and most constant variation of all the impurities in the coals examined. The best comparisons are, of course, on the run-of-mine coal, and indicate that the

ash will run higher in this grade of coal as marketed than in the mine sample. The coefficients determined, however, are sufficiently accurate for correcting the mine samples, provided they are taken by the method already recommended.

With regard to screened coal, the results are considered uncertain, and although the coefficient determined for this class of coal may be applied to mine samples for screened coal in general as compared to run-of-mine coal, it is not recommended that it be used for a specific grade of coal, such as lump or nut.

The coefficient determined for ash in slack coal, nearly 2, is considered good for determining the amount of ash in this grade of coal when it contains a large amount of fine dust, but it will probably be found that the coefficient will not give accurate results for special grades of slack or for coals free from fine shale partings and with good roofs and floors.

COEFFICIENTS.

The subjoined table contains all the coefficients determined from the results published in this paper. In this table the coefficients having a (?) after them are considered unreliable.

Coefficients for correcting mine samples approximately to commercial coal.

Moisture:	
For run-of-mine coal with less than 5 per cent in mine sample	1.19
For run-of-mine coal with more than 5 per cent in mine sample	.93
For screened coal (lump, egg, nut, etc.)	.97
For slack coal	1.30 (?)
Sulphur:	
For run-of-mine coal with less than 3 per cent in mine sample	1.07
For run-of-mine coal with more than 3 per cent in mine sample	1.06
For screened coal (lump, egg, nut, etc.)	1.10
For slack coal	.90 (?)
Ash:	
For run-of-mine coal with less than 7 per cent in mine sample	1.62
For run-of-mine coal with more than 7 per cent in mine sample	1.28
For screened coal	1.37
For slack coal	1.86

EXPERIMENTAL SAMPLING.

In order to demonstrate the variation in samples of coal, and the variation due to the different methods of treatment in sampling, the inspectors of the fuel-testing plant have carried on the experiments described in the following paragraphs at a mine in Williamson County, Ill. The coal in this mine is very hard, has a "blue band" of shale or clay near the bottom, and carries several small partings of bone. The ash content runs from 6 to 10 per cent, the sulphur ranges from 0.5 to nearly 2 per cent, and the moisture is about 9 per cent. Fig. 6 shows the sections of the coal bed at the places where the samples

were cut, as well as a map of that portion of the mine in which the samples were taken. On the map the letters A, B, C, etc., indicate

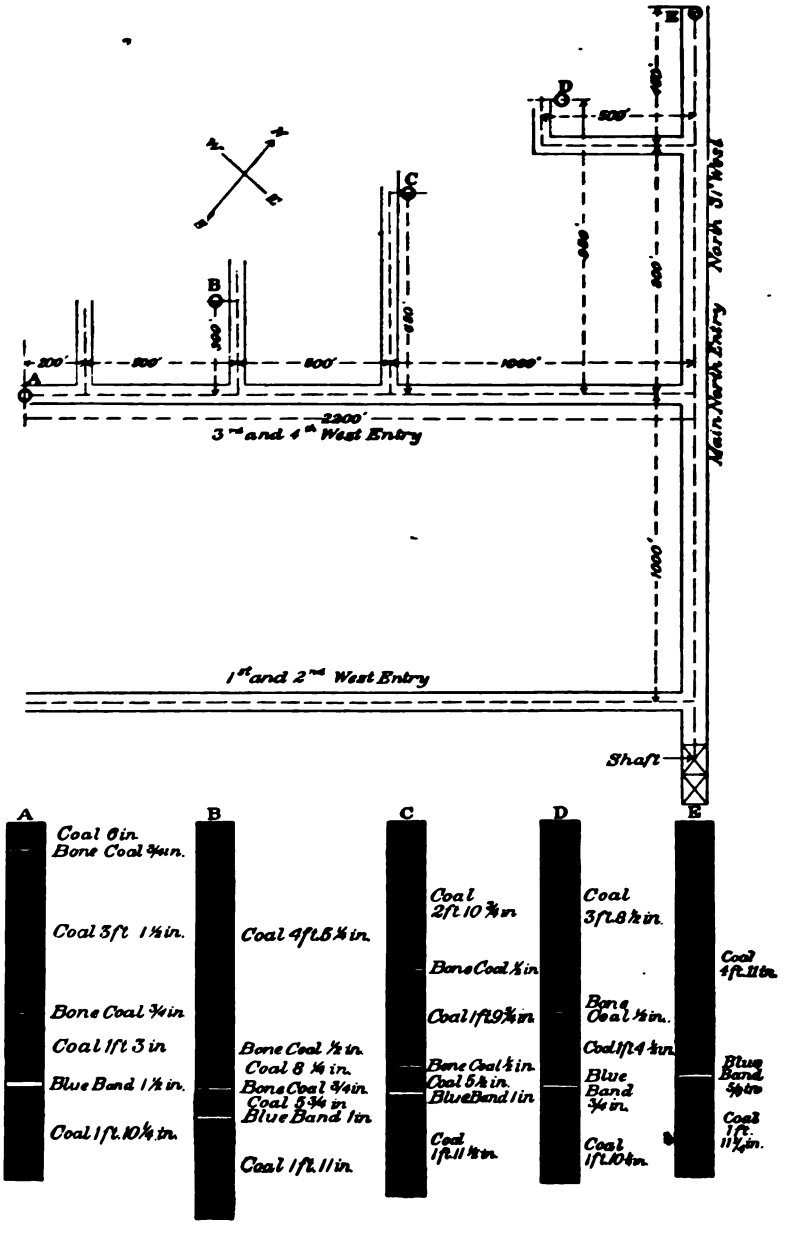

FIG. 6.—Map of mine and sections of coal used in sampling experiments.

the location of the corresponding sections, also lettered in the same *manner.*

The instructions for carrying on the experiments, the results of which appear in Table 10, were as follows:

Experiment No. 1: Take five samples in the usual manner (see mine-sampling, p. 487) about 500 feet apart in a straight line in that portion of the mine nearest the largest unworked body of coal. The rejected quarters of these samples are to be thoroughly mixed into one sample for analysis, the rejected quarters of the composite sample to be placed in a sack and sent to the chemical laboratory for analysis.

Experiment No. 2: At the place from which one of the above samples were taken [see map, fig. 6, D] secure another sample, crushing it in the usual manner to ½-inch mesh, and quarter down to two samples; place each half in a separate can, and the rejected quarters in sacks, quartering down if necessary to secure the necessary amount.

Experiment No. 3: From the same place in the mine secure as small a sample as possible to represent the total height of the bed and treat it in the usual manner, carefully noting the weight of the sample.

Experiment No. 4: From the same point [D] cut a sample from that part of the bed above the blue band, and one from that part of the bed below the blue band, and place them in separate cans, sending the rejected quarters to the laboratory in sacks.[a]

Experiment No. 5: From the same point [D] cut one sample the entire height of the bed, including the blue band. Break down to ½-inch mesh and then halve the sample by quartering. Prepare one half in the usual manner and place in can. Then crush the remaining half to ¼-inch size, and quarter down to can size. Place the rejected quarters of both these samples in separate sacks and send to the laboratory for analysis.

Experiment No. 6: From the same point in the mine [D] cut another sample and break up the largest lumps to not less than 1½-inch cubes and place the entire sample in a sack without crushing in the usual manner.

The results of these experiments are shown in Table 10. The "kind of sample" refers to the way in which the sample was packed for the laboratory. The regular metal cylinder with screw top sealed with adhesive tape was used for those samples marked "Can" and a light-weight canvas sack, such as is ordinarily used for this purpose, was used for the samples marked "Sack."

TABLE 10.—*Results of experimental sampling.*

	Experiment No. 1. (See map, fig. 6.)							Experiment No. 2.	
	Individual samples.					Composite sample.		First half of sample.	Second half of sample.
Kind of sample	Can	Can	Can	Can	Can	Can	Sack	Can	Can
Location in mine	A	B	C	D	E	A, B, C, D, and E	A, B, C, D, and E	D	D
Laboratory No.	3629	3628	3630	3631	3632	3633	3677	3634	3635
Weight of gross sample (pounds)	37	36	37	39	39	.....	.....	44	44
Moisture	8.72	8.80	9.02	8.63	8.88	9.00	6.97	8.85	9.29
Volatile matter	30.38	29.98	29.76	30.02	29.49	28.83	.....	29.28	29.16
Fixed carbon	53.28	52.77	52.79	52.95	53.60	54.12	.....	52.66	52.95
Ash	7.62	8.45	8.43	8.40	8.03	8.05	8.43	9.21	8.60
Sulphur	1.00	1.58	1.15	.99	.99	1.17	1.18	1.00	1.04

[a] Unfortunately one of these samples was lost in the mail, so that it was not possible to make the comparison.

TABLE 10.—*Results of experimental sampling*—Continued.

	Experiment No. 2.		Experiment No. 3, sample weighing 10 pounds.	Experiment No. 5.				Experiment No. 6, sample of 1½-inch cubes.	Car sample, lump coal.
	From first half of sample.	From second half of sample.		Through ¼-inch screen.		Through ½-inch screen.			
Kind of sample	Sack	Sack	Can	Can	Sack	Can	Sack	Sack	.....
Location in mine	D	D	D	D	D	D	D	D	.....
Laboratory No	3675	3676	3636	3638	3670	3637	3671	3672	3789
Weight of gross sample (pounds)	44	44	10	41	41	41	41	.....	.....
Moisture	7.08	7.13	8.80	9.00	6.99	8.90	6.79	6.73	7.78
Volatile matter	.....	.....	29.85	29.11	.....	29.29	.....	.....	29.85
Fixed carbon	.....	.....	53.83	52.19	.....	52.13	.....	.....	52.39
Ash	8.87	8.92	7.52	9.70	9.34	9.68	9.48	9.07	9.98
Sulphur	1.12	1.07	1.13	1.40	1.50	1.37	1.44	1.52	1.32

Experiment No. 1 was made to see to what extent samples from the same coal bed varied over a small area of the mine and also to see how the average of a number of samples compared with a composite sample made up of parts of the individual samples. A glance at Table 10 shows that the moisture in the five samples collected from the mine showed but slight variation, ranging from 8.63 per cent in sample D to 9.02 per cent in sample C. In these same samples the ash varied less than 1 per cent and the sulphur a little over 0.5 per cent. These results indicate that when the coal is fairly regular, one or two samples taken by the method already recommended will suffice in judging the quality of the coal. The composite sample, composed of the discarded portions of the five individual samples, compares very well with the average of those samples. The moisture in the composite sample shows 9 per cent, as compared with 8.81 per cent, the average for the five samples; the ash in the composite sample is 8.05 per cent, as compared with the average of 8.18 per cent for the five samples; and there is 1.17 per cent of sulphur in the composite sample, as compared with 1.14 per cent for the average sulphur in the five samples taken separately.

A striking and important result in experiment No. 1 is the comparison of the moisture in the composite sample sealed in a metal can with that in the discarded portions of this sample that were sent to the chemical laboratory in an ordinary canvas sack. The moisture in the can sample is 9 per cent; in the sack sample 6.97 per cent. This is a considerable loss in moisture, due to the method of packing, and the result not only misrepresents this important constituent, but affects the whole analysis.

Experiment No. 2 was made with the object of showing the importance of thoroughly mixing mine samples. In collecting the sample, one cut was made from the face of the coal, and the sample crushed and halved by quartering. As shown by the analysis in Table 10,

the results are not equal within the error of the chemical determinations involved, there being a difference of 0.44 per cent in moisture, 0.61 per cent in ash, and 0.04 per cent in sulphur. The sack samples obtained in this experiment show about the same loss in moisture as the sack sample obtained in experiment No. 1. The ash shows a smaller difference than the can samples and the sulphur is greater. This would seem to indicate that the difference between the two can samples in experiment No. 2 is due to some extent to the amount of moisture they contained.

Experiment No. 3 was made for the purpose of determining to what extent the quantity of coal taken for a sample affects the analysis. Ten pounds of coal was taken in this experiment, about 40 pounds being cut for the other samples. The analysis shows much less ash in this sample than in the others—7.52 per cent, as compared with 9.98 per cent in the car sample of lump coal. The other constituents, however, compare favorably with those in the heavier samples. The results of this experiment only emphasize the necessity of taking large samples.

Experiment No. 5 was made to learn to what extent the fineness of crushing affects the results. Half of the sample was crushed finer than one-half inch, and the other half finer than one-fourth inch. The analytical results show that the difference due to different fineness of crushing is insignificant below one-half inch. The sack samples taken in this experiment both lost about the same amount of moisture, showing also that there is very little difference in the drying out of one-half inch and one-fourth inch coal.

In experiment No. 6 a sample of 1½-inch cubes was sent to the laboratory in a sack, to see if forwarding the sample without crushing would assist it to retain moisture. The results of this experiment show a greater loss of moisture than in any of the others, the amount contained in this sample being 6.73 per cent. The ash content is 9.07 per cent and the sulphur 1.52 per cent.

CLASSIFIED LIST OF PAPERS DEALING WITH COAL, COKE, LIGNITE, AND PEAT CONTAINED IN PUBLICATIONS OF U. S. GEOLOGICAL SURVEY.

Compiled by WILLIS T. LEE and JOHN M. NICKLES.

Papers general in scope are given first, then those dealing with restricted areas, listed in chronologic order under the States arranged alphabetically.

The citation of a folio of the Geologic Atlas of the United States indicates that coal is found in the area and is more or less fully treated according to its economic importance.

STATISTICAL.

The reports on coal in the volumes of Mineral Resources of the United States contain, in addition to statistical matter, various other information. The statistics are given for the United States as a whole and for the States severally in alphabetic arrangement.

Mineral Resources of the United States. Albert Williams, jr. [For 1882-3], 1883: coal, pp. 1-107. Calendar years 1883 and 1884, 1885: coal, pp. 11-143; the manufacture of coke, by J. D. Weeks, pp. 144-213. Calendar year 1885, 1886: coal, pp. 10-73; the manufacture of coke, by J. D. Weeks, pp. 74-129.

Mineral Resources of the United States. David T. Day. Calendar year 1886, 1887: coal, by C. A. Ashburner, pp. 224-377; the manufacture of coke, by J. D. Weeks, pp. 378-438. Calendar year 1887, 1888: coal, by C. A. Ashburner, pp. 168-382; the manufacture of coke, by J. D. Weeks, pp. 383-435. Calendar year 1888, 1890: coal, by C. A. Ashburner, pp. 168-394; the manufacture of coke, by J. D. Weeks, pp. 395-441. Calendar years 1889 and 1890, 1892: coal, by E. W. Parker, pp. 145-286. Calendar year 1891, 1893: coal, by E. W. Parker, pp. 177-356; the manufacture of coke, by J. D. Weeks, pp. 357-402. Calendar year 1892, 1893: coal, by E. W. Parker, pp. 263-550; the manufacture of coke, by J. D. Weeks, pp. 551-602. Calendar year 1893, 1894: coal, by E. W. Parker, pp. 187-414; manufacture of coke, by J. D. Weeks, pp. 415-460.

Mineral Resources of the United States, 1894, nonmetallic products. Sixteenth Ann. Rept., pt. 4, 1895: coal, by E. W. Parker, pp. 1-217; manufacture of coke, by J. D. Weeks, pp. 218-304; origin, distribution, and commercial value of peat deposits, by N. S. Shaler, pp. 305-314.

Mineral Resources of the United States, 1895. Seventeenth Ann. Rept., pt. 3, 1896: coal, by E. W. Parker, pp. 285-542; coke, by J. D. Weeks, pp. 543-620.

Mineral Resources of the United States, 1896. Eighteenth Ann. Rept., pt. 5, 1897: coal, by E. W. Parker, pp. 351-632; coke, by E. W. Parker, pp. 659-746.

Mineral Resources of the United States, 1897. Nineteenth Ann. Rept., pt. 6, 1898: coal, by E. W. Parker, pp. 273–543; coke, by E. W. Parker, pp. 545–642.

Mineral Resources of the United States, 1898. Twentieth Ann. Rept., pt. 6, 1899: coal, by E. W. Parker, pp. 295–507; coke, by E. W. Parker, pp. 509–608.

Mineral Resources of the United States, 1899. Twenty-first Ann. Rept., pt. 6, 1901: coal, by E. W. Parker, pp. 321–519; coke, by E. W. Parker, pp. 521–633.

Mineral Resources of the United States. David T. Day. Calendar year 1900, 1901: coal, by E. W. Parker, pp. 273–457; coke, by E. W. Parker, pp. 459–536. Calendar year 1901, 1902: coal, by E. W. Parker, pp. 279–449; coke, by E. W. Parker, pp. 451–523. Calendar year 1902, 1904: coal, by E. W. Parker, pp. 289–447; coke, by E. W. Parker, pp. 449–515. Calendar year 1903, 1904: coal, by E. W. Parker, pp. 351–538; coke, by E. W. Parker, pp. 539–608. Calendar year 1904, 1905: coal, by E. W. Parker, pp. 381–577; coke, by E. W. Parker, pp. 579–648; peat, by H. H. Hindshaw, pp. 1229–1234. Calendar year 1905, 1906: coal, by E. W. Parker, pp. 453–714; coke, by E. W. Parker, pp. 715–766; peat, by M. R. Campbell, pp. 1319–1322.

TECHNOLOGICAL.

Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1894, E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. Bull. No. 261, 1905. 172 pp.

Survey work on coal during 1905, by M. R. Campbell. Bull. No. 285, 1906, pp. 203–210.

Gives a short account of geologic work on coal areas in 1905, of the work of the fuel-testing division, and of the classification of coals.

Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905. J. A. Holmes, in charge. Bull. No. 290, 1906. 240 pp.

Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. Prof. Paper No. 48, 1906. (In three parts.) 1492 pp.

AREAL.

GENERAL.

General account of the fresh-water morasses of the United States, with a description of the Dismal Swamp district of Virginia and North Carolina, by N. S. Shaler. Tenth Ann. Rept., 1890, pp. 303-304.

Discusses briefly the utilization of peat.

The coal fields of the United States, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 7-24.

Distribution and geologic relations of the various coal fields in the United States, classification of coals, production, and marketing.

The northern Appalachian coal field, by David White, M. R. Campbell, and R. M. Haseltine. Twenty-second Ann. Rept., pt. 3, 1902, pp. 119-226.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227-263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265-305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333-366.

An account of the coal field occupying parts of Missouri, Kansas, Nebraska, and Iowa.

The southwestern coal field, by Joseph A. Taff. Twenty-second Ann. Rept., pt. 3, 1902, pp. 367-413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415-471.

The coal fields of the Pacific coast, by George Otis Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473-513.

An account of the coals occurring in Washington, California, and Oregon.

Coal fields of the United States, by C. W. Hayes. Bull. No. 213, 1903, pp. 257-269.

A general account of the distribution and geologic relations of the coal fields, and the classification and marketing of coals.

ALABAMA.

The coal measures of Alabama, by E. A. Smith. Mineral Resources U. S. for 1892, 1893, pp. 293-300.

Stevenson folio, Alabama-Georgia-Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 19, 1895.

Gadsden folio, Alabama, description, by C. W. Hayes. Geologic Atlas U. S., folio 35, 1896.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227-263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The Warrior coal basin in the Brookwood quadrangle, Alabama, by Charles Butts. Bull. No. 260, 1905, pp. 357-381.

The Warrior coal basin in the Birmingham quadrangle, Alabama, by Charles Butts. Bull. No. 285, 1906, pp. 211-222.

ARIZONA.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1884-85. Bull. No. 27, 1886, p. 74.

Gives analyses of coal from Deer Creek Valley, Ariz.

The Deer Creek coal field, Arizona, by M. R. Campbell. Bull. No. 225, 1904, pp. 240-258.

ARKANSAS.

The coal fields of Arkansas, by J. C. Branner. Mineral Resources U. S. for 1892, 1893, pp. 303-306.

Preliminary report on the Camden coal field of southwestern Arkansas, by J. A. Taff. Twenty-first Ann. Rept., pt. 2, 1900, pp. 313-329.

The southwestern coal field, by J. A. Taff. Twenty-second Ann. Rept., pt. 3, 1902, pp. 367-413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

Fayetteville folio, Arkansas-Missouri, description, by G. I. Adams and E. O. Ulrich. Geologic Atlas U. S., folio 119, 1905, p. 6.

CALIFORNIA.

The coal deposits of California, by H. W. Turner. Mineral Resources U. S. for 1892, 1893, pp. 308-310.

Sacramento folio, California, description, by Waldemar Lindgren. Geologic Atlas *U. S., folio* 5, 1894.

Jackson folio, California, description, by H. W. Turner. Geologic Atlas U. S., folio 11, 1894.

Lassen Peak folio, California, description, by J. S. Diller. Geologic Atlas U. S., folio 15, 1895.

Marysville folio, California, description, by Waldemar Lindgren and H. W. Turner. Geologic Atlas U. S., folio 17, 1895.

The coal fields of the Pacific coast, by G. O. Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473–513.

An account of the coals occurring in Washington, California, and Oregon.

Coal in the Mount Diablo Range, Monterey County, Cal., by Ralph Arnold. Bull. No. 285, 1906, pp. 223–225.

COLORADO.

A report of work done in the division of chemistry and physics mainly during the fiscal year 1888–'89, by F. W. Clarke. Bull. No. 64, 1890, p. 55.

Gives analyses of coals from Gunnison County, Colo.

Coal fields of Colorado, by R. C. Hills. Mineral Resources U. S. for 1892, 1893, pp. 319–365.

Anthracite-Crested Butte folio, Colorado, description of the sedimentary formations, by G. H. Eldridge. Geologic Atlas U. S., folio 9, 1894.

Geology of the Denver basin in Colorado: Economic geology, by G. H. Eldridge. Monograph XXVII, 1896, pp. 317–387.

Includes an account of the coal resources and their development.

Elmoro folio, Colorado, description, by R. C. Hills. Geologic Atlas U. S., folio 58, 1899.

La Plata folio, Colorado, description: Economic geology, by C. W. Purington, Geologic Atlas U. S., folio 60, 1899, p. 14.

Walsenburg folio, Colorado, description, by R. C. Hills. Geologic Atlas U. S., folio 68, 1900, pp. 4–5.

Spanish Peaks folio, Colorado, description, by R. C. Hills. Geologic Atlas U. S., folio 71, 1901, pp. 4–6.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372–379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

The Yampa coal field, Routt County, Colo., by N. M. Fenneman and H. S. Gale. Bull. No. 285, 1906, pp. 226–239.

The Durango-Gallup coal field of Colorado and New Mexico, by F. C. Schrader. Bull. No. 285, 1906, pp. 241–258.

The Yampa coal field, Routt County, Colorado, by N. M. Fenneman and H. S. Gale. With a chapter on the character and use of the Yampa coals by M. R. Campbell. Bull. No. 297, 1906. 96 pp.

GEORGIA.

Ringgold folio, Georgia-Tennessee, descriptive text, by C. W. Hayes. Geologic Atlas U. S., folio 2, 1894.

Stevenson folio, Alabama-Georgia-Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 19, 1895.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227–263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

IDAHO.

Boise folio, Idaho, description, by Waldemar Lindgren. Geologic Atlas U. S., folio 45, 1898.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

ILLINOIS.

Danville folio, Illinois-Indiana, description, by M. R. Campbell. Geologic Atlas U. S., folio 67, 1900, pp. 6–7.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265–305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

Recent work in the coal field of Indiana and Illinois, by M. L. Fuller and G. H. Ashley. Bull. No. 213, 1903, pp. 284–293.

Patoka folio, Indiana-Illinois, description, by M. L. Fuller and F. G. Clapp. Geologic Atlas U. S., folio 105, 1904, pp. 7–9.

INDIANA.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265–305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

Ditney folio, Indiana, economic geology, by G. H. Ashley. Geologic Atlas U. S., folio 84, 1902, p. 7.

Recent work in the coal field of Indiana and Illinois, by M. L. Fuller and G. H. Ashley. Bull. No. 213, 1903, pp. 284–293.

Patoka folio, Indiana-Illinois, description, by M. L. Fuller and F. G. Clapp. Geologic Atlas U. S., folio 105, 1904, pp. 7–9.

INDIAN TERRITORY (OKLAHOMA).

Geology of the McAlester-Lehigh coal field, Indian Territory, by J. A. Taff. Nineteenth Ann. Rept., pt. 3, 1899, pp. 423–456.

An account of the stratigraphy of the field and the distribution and character of the coals.

Geology of the eastern Choctaw coal field, Indian Territory, by J. A. Taff and G. I, Adams. Twenty-first Ann. Rept., pt. 2, 1900, pp. 257–311.

An account of the stratigraphy and structure of the field, the distribution and character of the coal, and the mining developments.

Coalgate folio, Indian Territory, description, by J. A. Taff. Geologic Atlas U. S. folio 74, 1901, p. 6.

The southwestern coal field, by J. A. Taff. Twenty-second Ann. Rept., pt. 3, 1902. pp. 367–413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

Atoka folio, Indian Territory, description, by J. A. Taff. Geologic Atlas U. S., folio 79, 1902, p. 7.

Progress of coal work in Indian Territory, by J. A. Taff. Bull. No. 260, 1905, pp, 382–401.

Muscogee folio, Indian Territory, description, by J. A. Taff. Geologic Atlas U. S., folio 132, 1906, p. 6.

IOWA.

Sketch of the coal deposits of Iowa, by C. R. Keyes. Mineral Resources U. S. for 1892, 1893, pp. 398–404.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

KANSAS.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

Stratigraphy and paleontology of the upper Carboniferous rocks of the Kansas section, by G. I. Adams, G. H. Girty, and David White. Bull. No. 211, 1903, 123 pp.

Includes notes on the occurrence of coal beds.

Economic geology of the Iola quadrangle, Kansas, by G. I. Adams, E. Haworth, and W. R. Crane. Bull. No. 238, 1904, pp. 74–75.

Notes the occurrence of coal of no economic value.

Economic geology of the Independence quadrangle, Kansas, by F. C. Schrader and E. Haworth. Bull. No. 296, 1906. Coal, pp. 48–52.

Joplin district folio, Missouri-Kansas, description, by W. S. T. Smith and C. E. Siebenthal. Geologic Atlas U. S., folio 148, 1907, pp. 19–20.

KENTUCKY.

The coal fields of Kentucky, by J. R. Proctor. Mineral Resources U. S. for 1892, 1893, pp. 415–417.

Geology of the Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. Bull. No. 111, 1893, 106 pp.

Estillville folio, Kentucky-Virginia-Tennessee, description, by M. R. Campbell. Geologic Atlas U. S., folio 12, 1894.

Richmond folio, Kentucky, description, by M. R. Campbell. Geologic Atlas U. S., folio 46, 1898.

London folio, Kentucky, description by M. R. Campbell. Geologic Atlas U. S., folio 47, 1898.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227–263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265–305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

The Cumberland Gap coal field of Kentucky and Tennessee, by G. H. Ashley. Bull. No. 225, 1904, pp. 259–275.

Coal resources of the Kenova quadrangle, by W. C. Phalen. Bull. No. 285, 1906, pp. 259–268.

Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky, by G. H. Ashley and L. C. Glenn. Prof. Paper No. 49, 1906, 239 pp.

MARYLAND.

Piedmont folio, West Virginia-Maryland, description, by N. H. Darton and J. A. Taff. Geologic Atlas U. S., folio 28, 1896.

The bituminous coal field of Maryland, by David White. Twenty-second Ann. Rept., pt. 3, 1902, pp. 201–214.

MICHIGAN.

The northern interior coal field, by A. C. Lane. Twenty-second Ann. Rept., pt. 3, 1902, pp. 307–331.

MISSOURI.

The coal measures of Missouri, by Arthur Winslow. Mineral Resources U. S. for 1892, 1893, pp. 429–436.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

Joplin district folio, Missouri-Kansas, description, by W. S. T. Smith and C. E. Siebenthal. Geologic Atlas U. S., folio 148, 1907, pp. 19–20.

MONTANA.

The Laramie and the overlying Livingston formation in Montana, by W. H. Weed. Bull. No. 105, 1893, p. 105.

A brief statement regarding the occurrence and character of the coal beds.

Livingston folio, Montana, description, by J. P. Iddings and W. H. Weed. Geologic Atlas U. S., folio 1, 1894.

Three Forks folio, Montana, description, by A. C. Peale. Geologic Atlas U. S., folio 24, 1896.

Geology and mineral resources of the Judith Mountains of Montana, by W. H. Weed and L. V. Pirsson. Eighteenth Ann. Rept., pt. 3, 1898, pp. 614–616.

Gives an account of the coals mined in the area.

Fort Benton folio, Montana, description, by W. H. Weed. Geologic Atlas U. S., folio 55, 1899.

Little Belt Mountains folio, Montana, description, by W. H. Weed. Geologic Atlas U. S., folio 56, 1899.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Development of the Bear Creek coal fields, Montana, by C. A. Fisher. Bull. No. 285, 1906, pp. 269–270.

The North Dakota-Montana lignite area, by A. G. Leonard. Bull. No. 285, 1906, pp. 316–330.

NEBRASKA.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333–366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

Lignites of the middle and upper Missouri Valley, by E. F. Burchard. Bull. No. 225, 1904, pp. 276–288.

Describes the occurrence and character of lignite deposits in Dakota County, Nebraska, and in North Dakota.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372–379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

NEVADA.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Coal deposits between Silver Peak and Candelaria, Esmeralda County, Nev., by *J. E. Spurr. Bull. No.* 225, 1904, pp. 289–292.

Ore deposits of the Silver Peak quadrangle, Nevada, by J. E. Spurr. Prof. Paper No. 55, 1906, pp. 165–168.

Includes an account of the coal occurring in the area.

NEW MEXICO.

Report of work done in the division of chemistry and physics, mainly during the fiscal year 1885–86, by F. W. Clarke. Bull. No. 42, 1887, p. 147.

Gives an analysis of "natural coke" from Purgatory Canyon, N. Mex.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Coal fields of the White Mountain region, New Mexico, by C. A. Fisher. Bull. No. 225, 1904, pp. 293–294.

The Engle coal field, New Mexico, by W. T. Lee. Bull. No. 285, 1906, p. 240.

The Durango-Gallup coal field of Colorado and New Mexico, by F. C. Schrader. Bull. No. 285, 1906, pp. 241–258.

NORTH CAROLINA.

Report of work done in the division of chemistry and physics, mainly during the fiscal year 1885–86, by F. W. Clarke. Bull. No. 42, 1887, p. 146.

Gives analyses of coals from Gulf and from Stokes County, N. C.

Correlation Papers—the Newark system, by I. C. Russell. Bull. No. 85, 1892, coal, pp. 36–43.

The Atlantic coast Triassic coal field, by J. B. Woodworth. Twenty-second Ann. Rept., pt. 3, 1902, pp. 25–53.

NORTH DAKOTA.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Lignites of the middle and upper Missouri Valley, by E. F. Burchard. Bull. No. 225, 1904, pp. 276–288.

Describes the occurrence and character of the lignite deposits in Dakota County, Nebraska, and in North Dakota.

The lignite of North Dakota and its relation to irrigation, by F. A. Wilder. Water-Sup. and Irr. Paper No. 117, 1905. 59 pp.

The North Dakota-Montana lignite area, by A. G. Leonard. Bull. No. 285, 1906, pp. 316–330.

OHIO.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, 212 pp.

Huntington folio, West Virginia-Ohio, description, by M. R. Campbell. Geologic Atlas U. S., folio 69, 1900, pp. 5–6.

The bituminous coal field of Ohio, by R. M. Haseltine. Twenty-second Ann. Rept., pt. 3, 1902, pp. 215–226.

Coal resources of the Kenova quadrangle, by W. C. Phalen. Bull. No. 285, 1906, pp. 259–268.

OKLAHOMA. *See* Indian Territory.

OREGON.

Report of work done in the division of chemistry and physics, mainly during the fiscal year 1887–88, by F. W. Clarke. Bull. No. 60, 1890, p. 170.

Gives an analysis of coal from Pend d'Oreille, Oreg.

A geological reconnaissance in northwestern Oregon, by J. S. Diller. Seventeenth Ann. Rept., pt. 1, 1896, pp. 491–508.

Includes an account of the coal fields of northwestern Oregon.

Roseburg folio, Oregon, description, by J. S. Diller. Geologic Atlas U. S., folio 49, 1898.

The Coos Bay coal field, Oregon, by J. S. Diller. Nineteenth Ann. Rept., pt. 3, 1899, pp. 309-376.

The coal and pitch coal of the Newport mine, by W. C. Day. Nineteenth Ann. Rept., pt. 3, 1899, pp. 370-376.
Discusses the origin of the pitch coal.

Coos Bay folio, Oregon, description, by J. S. Diller. Geologic Atlas U. S., folio 73, 1901, pp. 4-5.

The coal fields of the Pacific coast, by G. O. Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473-513.
An account of the coals occurring in Washington, California, and Oregon.

Port Orford folio, Oregon, description, by J. S. Diller. Geologic Atlas U. S., folio 89, 1903, pp. 4-5.

PENNSYLVANIA.

Anthracite coal mining, by H. M. Chance. Mineral Resources U. S. for 1883 and 1884, 1885, pp. 104-131.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, pp. 212.

The stratigraphic succession of the fossil floras of the Pottsville formation in the southern anthracite coal field, Pennsylvania, by David White. Twentieth Ann. Rept., pt. 2, 1900, pp. 854-857.
An account of the occurrence of the Lykens coals in Stony Mountain and in the Dauphin basin.

The Pennsylvania anthracite coal field, by H. H. Stock. Twenty-second Ann. Rept., pt. 3, 1902, pp. 55-117.

The bituminous coal field of Pennsylvania, by David White and M. R. Campbell. Twenty-second Ann. Rept., pt. 3, 1902, pp. 127-200.

Masontown-Uniontown folio, Pennsylvania, description, by M. R. Campbell. Geologic Atlas U. S., folio 82, 1902, pp. 10-18.

Gaines folio, Pennsylvania, New York, description, by M. L. Fuller. Geologic Altas U. S.., folio 92, 1903, p. 9.

Brownsville-Connellsville folio, Pennsylvania, description, by M. R. Campbell. Geologic Altas U. S., folio 94, 1903, pp. 11-17.

Recent work in the bituminous coal field of Pennsylvania, by M. R. Campbell. Bull. No. 213, 1903, pp. 270-275.

The Barnesboro-Patton coal field of central Pennsylvania, by J. S. Burrows. Bull. No. 225, 1904, pp. 295-310.

The Elders Ridge coal field, Pennsylvania, by R. W. Stone. Bull. No. 225, 1904, pp. 311-324.

Coal mining along the southeastern margin of the Wilmore basin, Cambria County, Pa., by Charles Butts. Bull. No. 225, 1904, pp. 325-329.

Indiana folio, Pennsylvania, description, by G. B. Richardson. Geologic Atlas U. S., folio 102, 1904, pp. 4-6.

Latrobe folio, Pennsylvania, description, by M. R. Campbell. Geologic Atlas U. S., folio 110, 1904, pp. 12-15.

Kittanning folio, Pennsylvania, description, by Charles Butts. Geologic Atlas U. S., folio 115, 1904, pp. 12-13.

Mineral resources of the Elders Ridge quadrangle, Pennsylvania, by R. W. Stone. Bull. No. 256, 1905. Coal, pp. 31–54. Coke, p. 55.

Pittsburg coal in the Burgettstown quadrangle, Pennsylvania, by W. T. Griswold. Bull. No. 260, 1905, pp. 402–410.

Waynesburg folio, Pennsylvania, description, by R. W. Stone. Geologic Atlas U. S., folio 121, 1905, pp. 9–10.

Elders Ridge folio, Pennsylvania, description, by R. W. Stone. Geologic Atlas U. S., folio 123, 1905, pp. 7–9.

Rural Valley folio, Pennsylvania, by Charles Butts. Geologic Atlas U. S., folio 125, 1905, pp. 7–10.

Ebensburg folio, Pennsylvania, description, by Charles Butts. Geologic Atlas U. S., folio 133, 1905, pp. 7–9.

Beaver folio, Pennsylvania, description, by L. H. Woolsey. Geologic Atlas U. S., folio 134, 1905, pp. 11–12.

Economic geology of the Kittanning and Rural Valley quadrangles, Pennsylvania, by Charles Butts. Bull. No. 279, 1906. Coal, pp. 44–102.

Clearfield coal field, Pennsylvania, by G. H. Ashley. Bull. No. 285, 1906, pp. 271–275.

The Punxsutawney and Glen Campbell coal fields of Indiana and Jefferson counties, Pa., by F. B. Peck and G. H. Ashley. Bull. No. 285, 1906, pp. 276–279.

Economic geology of the Beaver quadrangle, Pennsylvania (southern Beaver and northwestern Allegheny counties), by L. H. Woolsey. Bull. No. 286, 1906. Coal, pp. 26–55.

Economic geology of the Amity quadrangle, eastern Washington County, Pennsylvania, by F. G. Clapp. Bull. No. 300, 1907. 145 pp.

Oil and gas fields of Greene County, Pa., by R. W. Stone and F. G. Clapp. Bull. No. 304, 1907. Map showing coal outcrops, in pocket.

Amity folio, Pennsylvania, description, by F. G. Clapp. Geologic Atlas U. S., folio 144, 1907, pp. 12–13.

Rogersville folio, Pennsylvania, description, by F. G. Clapp. Geologic Atlas U. S., folio 146, 1907, pp. 12–14.

RHODE ISLAND.

A report of work done in the Washington laboratory during the fiscal year 1883–84, by F. W. Clarke and T. M. Chatard. Bull. No. 9, 1884, p. 18.

Gives an analysis of coal from Cranston, R. I.

General geology of the Narragansett basin, by N. S. Shaler. Monograph XXXIII, 1899, pp. 79–88.

Describes the stratigraphy, occurrence, and character of the coal deposits in the Narragansett basin in Rhode Island.

SOUTH DAKOTA.

The lignites of the Great Sioux Reservation: A report on the region between the Grand and Moreau rivers, Dakota, by Bailey Willis. Bull. No. 21, 1885. 16 pp.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Edgemont folio, South Dakota-Nebraska, description, by N. H. Darton and W. S. T. Smith. Geologic Atlas U. S., folio 108, 1904, pp. 9–10.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372–379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

[illegible]

[illegible] Tennessee [illegible] by V. Hayes. [illegible]

[illegible] Tennessee [illegible] by V. Hayes. [illegible]

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[illegible] Tennessee [illegible] by V. Hayes. [illegible]

[illegible] Tennessee [illegible] by V. Hayes. [illegible]

[illegible] Tennessee [illegible] by Arthur Keith. [illegible]

[illegible] Tennessee [illegible] by Arthur Keith. [illegible]

[illegible] Tennessee [illegible] by Arthur Keith. [illegible]

[illegible] Tennessee [illegible] by M. R. Campbell. [illegible]

[illegible] Tennessee, description, by Arthur Keith. [illegible]

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. [illegible]

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The Cumberland Gap coal field of Kentucky and Tennessee, by G. H. Ashley. Bull. No. [illegible], 1904, pp. [illegible].

TEXAS.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1886-87, by F. W. Clarke. Bull. No. 55, 1889, p. 87.

Gives an analysis of coal from Burnet County, Texas.

The coal fields of Texas, by R. T. Hill. Mineral Resources U. S. for 1892, 1893, pp. 407-510.

Reconnaissance in the Rio Grande coal fields of Texas, by T. W. Vaughan. Bull. No. 101, 1893. 100 pp.

Uvalde folio, Texas, description, by T. W. Vaughan. Geologic Atlas U. S., folio 64, 1900, p. 5.

The southwestern coal field, by J. A. Taff. Twenty-second Ann. Rept., pt. 3, 1902, pp. 367–413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

UTAH.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1890–91, by F. W. Clarke. Bull. No. 90, 1892, p. 75.

Gives analyses of coals from Little Cottonwood gulch and from the Wasatch Mountains.

Coal fields of Utah, by Robert Forrester. Mineral Resources U. S. for 1892, 1893, pp. 511–520.

The Colorado formation and its invertebrate fauna, by T. W. Stanton. Bull. No. 106, 1893, pp. 35, 36.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Coal in Sanpete County, Utah, by G. B. Richardson. Bull. No. 285, 1906, pp. 280–284.

Notes on the Weber River coal field, Utah, by J. A. Taff. Bull. No. 285, 1906, pp. 285–288.

Book Cliffs coal field, Utah, west of Green River, by J. A. Taff. Bull. No. 285, 1906, pp. 289–302.

VIRGINIA.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1885–86, by F. W. Clarke. Bull. No. 42, 1887, p. 146.

Gives an analysis of "natural coke" from Midlothian, Va.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1886–87, by F. W. Clarke. Bull. No. 55, 1889, p. 87.

Gives analyses of coal and coke from Scott County, Va.

Correlation papers—the Newark system, by I. C. Russell. Bull. No. 85, 1892, coal, pp. 36–43.

The Clinch Valley coal fields, by A. S. McCreath and E. V. D'Invilliers. Mineral Resources U. S. for 1892, 1893, pp. 521–528.

Geology of the Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. Bull. No. 111, 1893, 106 pp.

Estillville folio, Kentucky-Virginia-Tennessee, description, by M. R. Campbell. Geologic Atlas U. S., folio 12, 1894.

Staunton folio, Virginia-West Virginia, description, by N. H. Darton. Geologic Atlas U. S., folio 14, 1894.

Pocahontas folio, Virginia-West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 26, 1896.

Tazewell folio, Virginia-West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 44, 1897.

Geology of the Richmond basin, Virginia, by N. S. Shaler and J. B. Woodworth. Nineteenth Ann. Rept., pt. 2, 1899, pp. 511–515.

Gives an account of the natural coke and bituminous coal of this area.

Bristol folio, Virginia-Tennessee, description, by M. R. Campbell. Geologic Atlas U. S., folio 59, 1899.

The Atlantic coast Triassic coal field, by J. B. Woodworth. Twenty-second Ann. Rept., pt. 3, 1902, pp. 25–53.

WASHINGTON.

A geological reconnaissance in central Washington, by I. C. Russell. Bull. No. 108, 1893, p. 76.

A brief note on the occurrence of coal of little economic value near Wenatchee.

Some coal fields of Puget Sound, by Bailey Willis. Eighteenth Ann. Rept., pt. 3, 1898, pp. 393–436.

Tacoma folio, Washington, description, by Bailey Willis and G. O. Smith. Geologic Atlas U. S., folio 54, 1899.

A preliminary paper on the geology of the Cascade Mountains in northern Washington, by I. C. Russell. Twentieth Ann. Rept., pt. 2, 1900, coal, pp. 205–206.

The coal fields of the Pacific coast, by G. O. Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473–513.

An account of the coals occurring in Washington, California, and Oregon.

A geological reconnaissance across the Cascade Range near the forty-ninth parallel, by G. O. Smith and F. C. Calkins. Bull. No. 235, 1904, p. 97.

Notes the occurrence of coal and coal mines in northwestern Washington.

Mount Stuart folio, Washington, description, by G. O. Smith. Geologic Atlas U. S., folio 106, 1904, pp. 9–10.

Coal in Washington, near Portland, Oreg., by J. S. Diller. Bull. No. 260, 1905, pp. 411–412.

Coal in Clallam County, Wash., by Ralph Arnold. Bull. No. 260, 1905, pp. 413–421.

Snoqualmie folio, Washington, description, by G. O. Smith and F. C. Calkins. Geologic Atlas U. S., folio 139, 1906, p. 13.

WEST VIRGINIA.

Coal mining in the Kanawha Valley of West Virginia, by S. M. Buck. Mineral Resources U. S. for 1883 and 1884, 1885, pp. 131–143.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1884–85. Bull No. 27, 1886, pp. 73, 74.

Gives analyses of coals from Randolph County, W. Va.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1887–88, by F. W. Clarke. Bull. No. 60, 1890, p. 169.

Gives analyses of coals and cokes from Piedmont, W. Va.

A report of work done in the division of chemistry and physics mainly during the fiscal year 1888–89, by F. W. Clarke. Bull. No. 64, 1890, p. 54.

Gives analyses of coals from Kanawha County, and of coal and coke from Tucker County, W. Va.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, 212 pp.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1889–90, by F. W. Clarke. Bull. No. 78, 1891, p. 128.

Gives analyses of coals from Barbour County, W. Va.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1890–91, by F. W. Clarke. Bull. No. 90, 1892, p. 75.

Gives analyses of coal and coke from Tucker County, W. Va.

The Potomac and Roaring Creek coal fields in West Virginia, by J. D. Weeks. Fourteenth Ann. Rept., pt. 2, 1894, pp. 567–590.

Geologic section along the New and Kanawha rivers in West Virginia, by M. R. Campbell and W. C. Mendenhall. Seventeenth Ann. Rept., pt. 2, 1896, pp. 473–511.
Describes the stratigraphy of the Coal Measures in this section. Includes analyses of the coals.

Pocahontas folio, Virginia-West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 26, 1896.

Piedmont folio, West Virginia-Maryland, description, by N. H. Darton and J. A. Taff. Geologic Atlas U. S., folio 28, 1896.

Franklin folio, West Virginia-Virginia, description, by N. H. Darton. Geologic Atlas U. S., folio 32, 1896.

Buckhannon folio, West Virginia, description, by J. A. Taff and A. H. Brooks. Geologic Atlas U. S., folio 34, 1896.

Tazewell folio, Virginia-West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 44, 1897.

Huntington folio, West Virginia-Ohio, description, by M. R. Campbell. Geologic Atlas U. S., folio 69, 1900, pp. 5–6.

Charleston folio, West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 72, 1901, pp. 6–9.

Raleigh folio, West Virginia, description, by M. R. Campbell. Geologic Atlas U. S., folio 77, 1902, pp. 4–8.

The Meadow Branch coal field of West Virginia, by M. R. Campbell. Bull. No. 225, 1904, pp. 330–344.

Coal in the Nicholas quadrangle, West Virginia, by G. H. Ashley. Bull. No. 260, 1905, pp. 422–428.

Coal resources of the Kenova quadrangle, by W. C. Phalen. Bull. No. 285, 1906, pp. 259–268.

WYOMING.

The coal fields of Wyoming, by G. C. Hewitt. Mineral Resources U. S. for 1893, 1894, pp. 412–414.

A geological reconnaissance in northwest Wyoming, by G. H. Eldridge. Bull. No. 119, 1894. Coal, pp. 49–62.

Coals and Coal Measures of Wyoming, by W. C. Knight. Sixteenth Ann. Rept., pt. 4, 1895, pp. 208–215.

Field observations in the Hay Creek coal field, by W. P. Jenney. Nineteenth Ann. Rept., pt. 2, 1899, pp. 568–587.
Includes some account of the coals of the area.

Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming, by N. H. Darton. Twenty-first Ann. Rept., pt. 4, 1901, pp. 582–584.
Gives an account of the distribution of coal in the Lakota formation in northeastern Wyoming.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415–471.

Coal of the Bighorn basin, in northwest Wyoming, by C. A. Fisher. Bull. No. 225, 1904, pp. 345–362.

Newcastle folio, Wyoming-South Dakota, description, by N. H. Darton. Geologic Atlas U. S., folio 107, 1904, pp. 8–9.

The coal of the Black Hills, Wyoming, by N. H. Darton. Bull. No. 260, 1905, pp. 429–433.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372–379.
Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

Sundance folio, Wyoming-South Dakota, description, by N. H. Darton. Geologic Atlas U. S., folio 127, 1905, p. 12.

Aladdin folio, Wyoming-South Dakota-Montana, description, by N. H. Darton and C. C. O'Harra. Geologic Atlas U. S., folio 128, 1905.

Mineral resources of the Bighorn Mountain region, by N. H. Darton. Bull. No. 285, 1906, pp. 303–310.
Includes an account of coal deposits in northeastern Wyoming.

Mineral resources of the Bighorn basin, by C. A. Fisher. Bull. No. 285, 1906, pp. 311–315.
Includes an account of the coal of the area.

Coal and oil in southern Uinta County, Wyo., by A. C. Veatch. Bull. No. 285, 1906, pp. 331–353.

Geology of the Bighorn Mountains, by N. H. Darton. Prof. Paper No. 51, 1906, pp. 62–67, 111–112.
Gives an account of the stratigraphy, character, and mining of coal in the Bighorn Mountains of Wyoming.

Geology and water resources of the Bighorn basin, Wyoming, by C. A. Fisher. Prof. Paper No. 53, 1906, pp. 46–56.
Describes the character, occurrence, and development of the coal deposits of the area.

Bald Mountain-Dayton folio, Wyoming, description, by N. H. Darton. Geologic Atlas U. S., folio 141, 1906, p. 14.

Cloud Peak-Fort McKinney folio, Wyoming, description, by N. H. Darton. Geologic Atlas U. S., folio 142, 1906, p. 15.

Devils Tower folio, Wyoming, description, by N. H. Darton and C. C. O'Harra. Geologic Atlas U. S., folio 150, 1907, p. 8.

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[Bulletin No. 316.]

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